JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIX. FEBRUARY, 1885. No. 2.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

ELECTRO-METALLURGY.*

BY NATHANIEL S. KEITH.
Secretary of the American Institute of Electrical Engineers, editor of the "Electrical World," etc.

MR. KEITH, who was introduced by Dr. William H. Wahl, Chairman of the Lecture Committee, spoke as follows:

LADIES AND GENTLEMEN:—I have this evening that which may be called a dry subject upon which to speak. I shall do my best to make it interesting to you, but cannot hope to succeed in imparting a full knowledge of the subject in one short lecture. It is a subject of intense interest to the chemist and to the electrician, for it combines principles underlying its practice which belong to both professions. In fact, the man skilled in its science and art may appropriately be styled an electro-chemist.

The art is only of comparatively recent growth. Its fundamental features have come to light, from time to time, only during the past century of years, and its principles have only been outlined, investigated and understood during the last thirty or forty years. Its broad, extensive and economical practice has only come to be possible within the last decade—since the practical development of dynamo-electric

*A lecture delivered at the International Electrical Exhibition of the Franklin Institute, Tuesday, September 23, 1884.

machines, such as we see in this Exhibition in such great variety of forms and capacity, at work producing electricity for lighting and other purposes.

Unfortunately there is but a poor exhibit in numbers of dynamo-electric machines specially constructed for electro-metallurgical work. We will presently consider what this special construction should be.

We might devote considerable time to an account of the history of the art; but there is so much more of practical interest to be considered in the way of experiments and descriptions during the time allotted to me, that I will only glance at the course of its rise.

The art may be said to have originated with Volta, who made the first chemical electric battery, and demonstrated that metallic salts could be decomposed into their constituent parts, and that water could be resolved into gases—oxygen and hydrogen. This was in the year 1799. After this time there were many experimenters with the voltaic pile and with various voltaic batteries in producing the electro-chemical decomposition of various metallic salts in solutions; but it was not until after 1830, fifty years ago, that the facts known came to be applied to any practical purpose. About this time the form of voltaic battery called the Daniell cell was invented by Daniell.

During the few years immediately succeeding the year 1830, Jacobi, Spencer, De la Rue, Daniell himself, and others were experimenting with this battery for various purposes, but mainly in the way of discovery. Some, if not all of the experiments which I am about to show you were performed by these distinguished men. Many of these things, which now seem to us so common and obvious, were then the subjects of great wonderment and of scientific discussion.

So, then, when either Spencer or Jacobi first announced that the deposit of copper, which takes place in a Daniell cell, could be removed from the metal upon which it had been deposited and that the face of the removed deposit had in reverse all of the marks, whether depressions or protuberances of the face of the metal which had received the deposit, it excited much notice and comment, in fact a scientific *furore*. The Daniell cell, by the way, is a good illustration for us to consider in relation to the principles of electro-metallurgy; therefore we will take it up later on.

Experimenters and inventors took the facts that had accumulated at that time, and from them and others evolved the art of electro-metallurgy, which has scarcely been improved in conception and execution

during the past twenty years. The improvements, or such new things as I may so designate, are in the manner and means of producing electricity and in special applications of electricity so produced. The modern practical electro-metallurgy rests upon the principles and speculative ideas of men of 30 or 40 years ago, and on the more modern dynamo-electric machine, by the aid of which we are able to produce electricity in any quantity, any quality, more reliably, with far less trouble and for less than one-twentieth of the expense incurred with galvanic batteries.

The principles and laws governing the art of electro-metallurgy were well laid down by Smee, who wrote a book on the subject in 1840. The book made Smee famous, and his name will always be coupled with the art on which he conferred the name, "Electro-Metallurgy." We are now able, with the latest modern appliances for the production of electricity, to apply the principles laid down by Smee to the renewed art, made so much broader in its scope, because so much more economically and reliably to be pursued. I refer more especially to production and purification of metals, and the separation of them from one another, and the production and reproduction of works of art and to similar purposes.

Enough has been said about the history of the art; we will, therefore, proceed to consider its principles, and we can best do so by showing a few experiments and making remarks upon the phenomena which you will observe. We have here a lantern which will produce upon the screen a picture of those things which my assistant may put before it.

I have had prepared several glass cells, containing different liquids, and we will place them in succession before the lantern, and their contents will be shown on the screen, and we will also be able to see the actions which go on in the cells. By considering these things I hope to be able to give you a pretty fair idea of the principles involved in this beautiful art.

We have in this first cell dilute sulphuric acid. We immerse in it a rod of the metal zinc. Observe the action. Bubbles of gas form on the zinc, rise rapidly to the surface of the liquid and escape in the air. Now, whoever first noticed this phenomenon did not know what this gas was, nor the reasons for the appearances. Many years of experimental research and indulgence in hypothesis, theory and controversy were spent before the conclusions we now state as facts were

adopted in relation to this and the other points which we will consider to-night. But our time is too short to allow us to indulge in anything but a statement of facts, and accepted theories for the facts, we may observe. The gas is hydrogen; it comes from the water of the diluted sulphuric acid; water is composed of oxygen and hydrogen; the oxygen has combined with the zinc to form oxide of zinc; the oxide of zinc is dissolved by the liquid because some of the sulphuric acid radical (SO_3) combines with the oxide of zinc to form sulphate of zinc ($ZnSO_4$), which is soluble in water. This action will continue until all of the zinc is dissolved, or until all of the acid constituent of the liquid is exhausted. Then, in the latter case, oxide of zinc will be formed as a sort of coating over the metallic zinc. This coating, being insoluble in the water remaining, will act to protect the zinc from further chemical action.

We observe that the liquid rises in temperature as this action proceeds. What do we deduce from that? Heat is a manifestation of active energy, that is, energy which is being freed from one material and being absorbed by another or others. But where does this energy come from? When the zinc was separated from the mineralizing constituent, oxygen, (which compound constituted its ore) heat was used to effect the decomposition, and a portion of the energy which the heat represented was absorbed by the zinc, and became *latent* as it is sometimes expressed.

Now, metallic zinc has a continual tendency for union with oxygen, and such union takes place whenever the conditions are favorable. In uniting again with oxygen, just as much heat is given out as was absorbed during the process of freeing it from the oxygen originally combined with it in the ore. Immersion of zinc in dilute sulphuric acid is a condition extremely favorable to its oxidation. As zinc under these conditions has a greater affinity for oxygen than hydrogen has, it displaces the equivalent of hydrogen and combines with the oxygen, with production of heat, which shows itself in the elevation of the temperature of the dilute acid. Conversely: if we separate the zinc from the oxygen and the acid, we must, to so do, apply energy in some of its modes, such as heat or electricity.

Now, in the second cell which I will bring to your notice, I have some of the same dilute sulphuric acid, and immersed in it are two rods of metal. One of these is of copper and the other of zinc. But the surface of the zinc is covered with mercury, for the purpose of pro-

tecting the zinc from direct action of the acid on it. Mercury has been found to perform this office, and without impairing the qualities of zinc for the purposes of the galvanic battery.

You will observe that as long as the two rods are separated the liquid remains quiet, there is no boiling—escape of gas—as in the former experiment. We learn, by the fact of the copper rod being unaffected, that copper has less affinity for oxygen than hydrogen has; and that, although zinc has a greater affinity, it is prevented from exercising it by the protective coating of mercury which has even a less affinity for oxygen than has copper.

By carrying on a similar line of experiments with other metals and other liquids we would learn that the various metals have differently valued affinities for oxygen, some more than others, so that a scale-list may be made out in which the metals will be arranged in the order of their several affinities for oxygen, or for chlorine. Those which have the strongest affinities are called electro-positive, while those with less strong affinities are called electro-negative in relation to the others. Thus every metal, except the extremes of the list, is electro-positive to some of the list and electro-negative to the others.

Now, if we touch these two metal rods together, immediately torrents of gas bubbles are seen to proceed from the surface of the copper rod, rise to the surface of the liquid and escape into the air. It will also be noticed that the action is even more violent than in the first instance. If we separate the rods the action ceases at once, and is immediately resumed on retouching.

The gas escaping is hydrogen, as in the first experiment. But it rises from the copper instead of the zinc. The copper, however, is not dissolved, but the zinc is, as before; and the action will continue as in that case. So far we have not seen any evidences of electricity. But if we connect the zinc and the copper rods by means of a wire running through some electrical instrument, say a galvanometer, that magnetic action takes place in the instrument, which, we know, shows the existence of a current of electricity.

This experiment is often shown in illustrating the genesis of the galvanic battery. A galvanic battery is but an electro-metallurgical apparatus. The principles which govern batteries are electro-metallurgical, because they are those which govern the affinities of metals both in the production and utilization of electricity.

It has been found that the setting free of gaseous hydrogen absorbs

some of the energy of the union of zinc with oxygen and acid. This is the case whether in a galvanic battery, or in an electrolytic bath wherein electricity is effecting chemical changes. Therefore it is desirable to avoid this formation of free hydrogen. In some galvanic batteries this is done by providing at the copper rod, or plate, (or at the negative material) some material which will absorb the hydrogen as fast set free. In electro-metallurgy, strictly speaking, this is also desirable, in order to avoid waste of energy which necessitates the use of more materials in the shape of coal or chemicals to produce the electricity needed to supply the waste of energy in the electrolytic bath.

I am showing and explaining these elementary experiments to illustrate, step by step, some of the principles which govern electro-metallurgical problems, and for use subsequently when I come to the applications of the principles involved.

In the two experiments just shown, hydrogen gas has been shown in both. I have arranged an experiment in which oxygen is set free. But previously to showing it, I will give another in which a metal is set free. The liquid in this vessel is an aqueous solution of acetate of lead, commonly called sugar of lead. After we immerse this rod of zinc in it, as we did in the case with the dilute acid, instead of bubbles of gas escaping, the rod appears to increase in diameter with a gradual growth. We learn from this experiment that zinc reduces lead from its solution, enters into solution in place of the lead, in a manner analogous to the substitution to produce hydrogen. But as lead is not gaseous, it remains in the liquid clinging to the remaining zinc. This action will continue until the zinc has completely been dissolved, or until all the lead in the solution has been reduced from it to a metallic state. The liquid also rises in temperature, but not so much as in the first or second experiments. This is because the production of metallic lead absorbs some of the energy set free by the zinc, and that energy is not used to heat the liquid.

It will be noticed that the reduced lead is in a very finely divided state, an aggregation of minute crystals appearing to the eye like a flocculent mass. This is generally the case under like circumstances with all metals reduced from their solutions by other metals.

In the experiments thus far shown we have seen the substitution, merely of an electro-positive metal for some electro-negative constituent of a solution. We have learned that this action sets free the

amount of energy which belongs to the union of the electro-positive metal with oxygen and acid, over and above that energy which belongs to the like union of the electro-negative material with the same constituents; and that this extra energy is manifested as heat in the increase of temperature of the liquid.

Now, from our other observations, it is plain, that if we desire to substitute electro-negative materials for electro-positive ones in liquids we must apply energy in some form to the liquids containing such constituents. Heat alone does not suffice; but electricity does, so that we are enabled to make many of these substitutions which can only be made, if at all otherwise, by long, tedious, and expensive chemical and metallurgical processes. Chemical and metallurgical processes are merely those of substitution of one material for another, during which energy in some of its modes takes active part, either to be set free or absorbed. Electricity is the most manageable mode of energy, and it seems that by its aid, being so easily controlled, a much wider use of it in chemistry and metallurgy is to be made than now. Especially is this the case since its production in any quantity and quality is so cheap and easy by means of dynamo-electric machines.

I have prepared an experiment *apropos* to this stage of my lecture, which, though it is an old one, familiar to many of you from your school days, I shall venture to repeat it here.

In this vessel is dilute sulphuric acid, and two platinum strips separated from each other. One of these platinum strips is connected by a wire with one of the poles of a galvanic battery, and the other strip with the other pole of the battery. Platinum is used because its affinity for oxygen and acid is so slight that even an electric current will not cause them to unite. You will observe that, now the battery circuit has been completed, torrents of gases escape from both the platinum strips, and that from one of them twice as much in volume is produced. The lesser volume is oxygen and the other hydrogen. The galvanic battery supplies the energy needed to effect the decomposition of the water; and more energy, this is more battery power, is required than would be the case if the strip from which the oxygen is escaping was of a metal which would absorb oxygen and be dissolved by the acid liquid. Because this latter action would contribute some energy (that due to the union of the metal with oxygen and acid) to the circuit of the operation.

I have three cells of Daniell battery connected in the order called

"series," so as to have sufficient electro-motive force, (or pressure) of electricity to effect the decomposition. Neither one nor two cells will furnish pressure enough. From this and other experiments of analogous character with other liquids we learn that various electro-motive forces are requisite to effect decompositions of various liquids. We also learn that the needed electro-motive forces are also varied by the kinds of metals which are in the liquids and connected with the poles of the battery.

The vessel and contents are called the "bath." The liquid is called the "electrolyte." The metals, collectively, are called "electrodes." That metal which is connected by the wire to the positive, or copper plate of the battery is called the "anode;" and the other metal which is connected by its wire to the negative, or zinc plate of the battery is called the "cathode." And the wires are called the "positive" and "negative conductors," respectively. These names are applied, no matter what may be the kind or shape of the metals, bath, vessel, electrolyte or other parts.

This is the simplest form of electrolytic arrangement, but of little present utility; though it has possible applications in the arts, such as in the production of oxygen and hydrogen gases.

This kind of a bath, modified so as to collect and retain the gases for measurement, is used by the electrician for measuring electricity quantitatively. Such an arrangement is called a "voltameter." Its value as a measure is based upon the fact that a given quantity of electricity effects a given quantity of chemical decomposition, or of chemical composition, as the case may be. This is the case, no matter what may be the composition of the liquid or its contents. A definite current effects a definite chemical action, and one is the exact measure of the other. The only difference physically is in the weight and volume of the respective materials produced by composition and decomposition. Thus a given current will set free 1 grain of hydrogen, 8 grains of oxygen, 31·75 grains of copper, 103·7 grains of lead, 108 grains of silver, and so on with all substances in the ratio of their several electro-chemical equivalents. These electro-chemical equivalents are not always the more modernly recognized chemical equivalents, but are those which represent the chemical equivalent of 1 grain of hydrogen; say, like the older equivalent numbers.

Following these facts we may construct and use copper, lead, zinc and other voltameters for use in measuring electricity. In fact such

are used, and with greater advantages in some cases. For instance, the gas voltameter requires a battery as we have seen, of considerable electro-motive force, because the voltameter exerts a counter-electro-motive force, by reason of the fact that no composition takes place in the apparatus. (Remember that decomposition requires energy to effect it, while composition does not.) But we may construct a voltameter which requires no energy, except to overcome the electrical resistance of its parts. For instance two copper electrodes in an electrolyte of a solution of sulphate of copper. In this the composition and decomposition are exactly alike:—as much energy is contributed to the circuit by the dissolving of the copper anode as is absorbed from the circuit by the depositing of copper on the cathode. It is well to remember this for another reason: It is a form of electrolytic bath in most extensive use, and is a type of many others constituted for and of other metals.

We may construct a voltameter which will contribute energy to the circuit. Use an anode of pure amalgamated zinc; a cathode of platinized platinum, and an electrolyte of dilute sulphuric acid. As zinc in dissolving contributes more energy to the circuit than is used in setting free hydrogen, such an apparatus, arranged to retain the hydrogen in a graduated receptacle, may be used in a voltameter, with the understanding that only hydrogen, not the two gases, as in the first case, is to be considered.

The principles illustrated by this experiment and the several analagous ones spoken of, are those which must be closely considered in all electrolytic work; therefore it is well to bear them well in mind.

The next experiment is designed to illustrate the production of a metal from a solution of one of its salts by means of electricity. We have a cell as in the last experiment, and with like electrodes of platinum. But in place of an electrolyte of dilute sulphuric acid, we have an aqueous solution of acetate of lead, the same as in the third experiment. We now connect the battery and we immediately observe gas rising from the anode, and shortly a beautiful arborescent, crystalline, growth taking place on the cathode. We have learned that oxygen under electrolytic action goes to the anode, and when the material of the anode cannot combine with or absorb it, it escapes to the atmosphere. Therefore this gas is oxygen. We have also learned that the metal constituent of an electrolyte goes to the cathode. As the metal

constituent of acetate of lead is lead, these beautiful crystals of leaf-like form are of that metal.

Observe how they increase in size. In a short time they will grow until they will touch the anode, and then they will cease to grow because the electrolytic action will cease by reason of the electricity passing from anode to cathode by way of the lead crystals instead of by the electrolyte.

We learn from this experiment that by the aid of electricity metals may be recovered from their solutions; that such is the case only when the metal is more electro-negative than the other constituents; that less battery power is required in this case, at least, than in separating hydrogen from an electrolyte; that the evolution of oxygen requires more battery power than is the case when the oxygen is either absorbed by, or combined with, the material of the anode; and that some at least of the metals are electrically deposited in a separated crystalline state. This is the fact with tin and some other metals. It has hitherto been found impracticable to produce a "reguline," deposit of these two metals. We mean by "reguline," adhesive and cohesive, so that the metal has the characteristics ordinarily belonging to sheets and masses. The reguline condition is that of the greater number of deposits made in electro-metallurgy.

The next experiment which I have arranged is for the purpose of illustrating that which is called "true electrolysis." That is to say, wherein the action and reaction, the dissolving and depositing of metal are in equal quantities. From the anode exactly as much metal will be dissolved as is deposited on the cathode. In this cell both electrodes are of lead, and the electrolyte is a solution of acetate of lead. I use a lead solution because the action can be seen so much easier on account of the character of the deposit pointed out in the last experiment.

Now, when I connect the battery wires with the electrodes there is no commotion in the electrolyte as in the last experiment. The oxygen combines with the lead and the oxide of lead is dissolved by the liquid, while the deposition of lead goes on quietly, and the crystals grow as in the last experiment. We learn by studying the phenomena of this experiment that exactly the same weights of lead are dissolved and deposited; that the electrolysis may go on until the anode be completely dissolved; and that at the end the electrolyte will have as much lead in it as at the start. We furthermore learn that no electric energy is absorbed in this action proper. The only electric energy which

is required is that to carry the electricity through the liquid—to overcome the electric resistance of the electrolyte. The energy required to effect the deposition of the metal on the cathode is contributed by the dissolution of the metal of the anode.

The principles of the third experiment—the one in which zinc was immersed in a solution of lead to show the substitution of lead for zinc—are carried into practice extensively, but with another metallic solution, namely, that of sulphate of copper.

In many copper mines, decomposition of the copper ore is continually going on, and copper salts are produced which are dissolved by the waters of the mines. These solutions are called "mine waters." They consist mainly of sulphates of copper and iron. Copper is obtained from this sulphate by a process analagous to the production of lead from solutions by means of zinc; only in place of using zinc, a comparatively inexpensive metal, iron, in the form of scrap-iron, is used.

As the mine waters come from the mine they are caused to flow through long troughs in which are placed large quantities of scrap-iron. As the water passes over this iron the sulphuric acid constituent leaves the copper and combines with the iron, because it has a greater affinity for iron than it has for copper. The copper is left as a dark reddish-brown powder, and is removed from the troughs, from time to time, and smelted to bring it into marketable shape. In place of running to waste as sulphate of copper, iron is substituted for the copper, and it runs away in the shape of sulphate of iron.

If it were possible to prevent oxydation of the iron each 28 pounds of iron would gain 31·75 pounds of copper. But as the iron is generally rusty at the start, and rusts more during the process, the fine powder of copper comes from the troughs much mixed with iron rust, or oxide, and considerable less than the equivalent of copper for the iron expended is obtained. But the expensive copper is gained for the much less expensive waste-iron.

Some years ago I devised a process and apparatus calculated to avoid this admixture. Large vessels contain large porous jars, after the plan of various galvanic batteries, only immensely larger. Iron and slightly acidulated water are placed in the porous cells, and the mine-waters are allowed to slowly flow into and out of the outer vessels, in which thin sheets of copper are placed. The iron in the porous cells is electrically connected by wires with the copper plates. The iron is dissolved and copper is deposited on the copper plates. Elec-

tricity is generated by this action, as it is in the cases of all substitutions, and it flows through the wires from copper to iron. This electricity may be utilized for many purposes.

The finely divided copper from mine-waters is called "cement-copper," and is produced in large quantities in South America and other sections. Most of it is taken to Swansea, in Wales, to be smelted and refined.

Some of the mine waters carry silver in solution as well as copper. As iron reduces silver, as well as copper, from its solutions, much cement-copper is produced which contains silver enough to be profitably separated. This separation has been largely done by electrolysis; which operation also, at the same time, refines the copper by separating its other impurities. The cement-copper is laid on an insoluble anode-plate, carbon, for instance, in a solution of copper sulphate. A cathode of copper sheet is suspended horizontally in this electrolyte above the anode. A current of electricity causes the dissolving of the copper while the silver contents, and the gold and other metals electro-negative to copper remain undissolved. When the copper has thus been removed the residues are gathered and smelted for their contents of silver and gold. Iron enters into the solution provided any be present in metallic state or as protoxide. But no iron is deposited on the cathode as long as copper sulphate be present in the electrolyte and in contact with the cathode; and even if no copper be present iron will not be deposited if the electrolyte be acid. If the electrolyte be neutral then iron may only be deposited on the cathode by having the difference of potential (the pressure of the current) between the electrodes greater than that which is due to the difference of electro-motive forces of copper and iron.

The separation of copper from its solutions by means of iron substitution has other applications than that to mine-waters. Solutions of copper are produced in various wet processes for treatment of copper ores. The mother-liquors of the process of making crystals of sulphate of copper must be treated from time to time, when they become impure, for the separation of their copper contents.

It is proposed to use dynamo-electric machines to effect the deposition of this copper. It is claimed that the cost of deposition will be less and a purer product be gained, and this in spite of the fact that more electric energy must be applied to effect the separation than is the case where a soluble anode is used, as in true electrolysis. In this case

oxygen must be set free and escape as gas. This requires the expenditure of energy to overcome, not only the electrical resistance of the apparatus and electrolyte, but the difference of the electro-motive forces of oxygen and copper.

The substitution in solutions of one metal for another such as we we have spoken of was known to the ancient alchemists. A base metal could be by simple immersion apparently converted to another, so the charlatans of those days deceived the potentates and rich men of their time into the belief in the transmutation of metals.

By the next experiment I will illustrate to you the electro-plater's art. In this glass vessel I have a solution of silver. It is silver cyanide dissolved in a solution of potassium cyanide. This electrolyte is so constituted for reasons too numerous and complicated to consider at this time. Silver cyanide is insoluble in water, but it is readily soluble in an aqueous solution of potassium cyanide. In this vessel is a plate of silver connected by this wire with the positive pole of a source of electricity; in this case an Edison electric-light machine; the one which furnishes the current for the lights in this hall. The plate of silver is, therefore, an anode; and this plate of copper is to be the cathode of this plating bath.

You will notice that in a short time after I dip this copper plate into the silver electrolyte in the vessel, the copper plate will have received a beautiful dead-white coating of silver. The operation is as follows: The silver cyanide splits into silver and cyanogen. Silver being electropositive in its relation to cyanogen goes to the cathode. Cyanogen being electro-negative in its relation to silver goes to the anode, where it combines with more silver from the anode to form silver cyanide which is dissolved by the potassium cyanide solution. This splitting up and combination goes on continually during the pasage of electricity; and the deposit of silver continues as long. Just as much silver enters solution as is deposited, so that the electrolyte may be considered a vehicle for carrying silver across from anode to cathode. When the deposit becomes thick enough, supposing this plate to be an urn, pitcher, knife, spoon or other article, the article is removed, the adhering solution washed off, dried, and then rubbed with a hard, smooth instrument called a burnisher to give it the brilliantly polished appearance so familiar to all of us in silver-plated articles.

This operation serves to illustrate the plater's art. The principles are substantially the same whether the electrolyte be one of silver

solution or of a solution of gold, copper, nickel, brass, iron, lead, or zinc. The anode must be soluble in the electrolyte only when energized by electricity. The cathode must be insoluble in the same electrolyte, or otherwise it would be dissolved in the process of substituting its metal for the proper metal of the electrolyte.

Some so-called electro-plating solutions are sold by peddlers and others to the unsuspecting housewives. Many of these plating solutions are such that the articles to receive the coating are electro-positive to silver, and therefore displace silver by substitution. Such coatings are always the merest films, and not well-adherent, and therefore are of little value. In plating baths, when the article reduces the metal of the bath upon itself it is said to produce a local action. In such cases the deposit which may be made by electricity will not be coherent. For instance, iron is electro-positive to copper in an electrolyte of copper sulphate; it reduces some of that copper upon itself; it cannot receive an adherent deposit in such a solution. So, when iron is to be copper-plated it must receive somewhat of a copper coating in an electrolyte in which iron is not electro-positive to copper. Such an electrolyte is found in copper cyanide. As soon as it has received a slight coating, enough to cover it from access of copper sulphate to the iron, it is usually removed to a copper sulphate bath, which is cheaper in constitution and more easily worked than in the cyanide bath.

In depositing some metals, notably gold, brass, nickel, etc., the deposit of metal is not the equivalent of the amount dissolved from the anode. In such cases, gases are evolved from the electrodes. When gases are evolved more electrical energy is necessarily expended than would otherwise be necessary, and the metal deposited is not the true equivalent due to the quantity of electricity used. But the metal deposited and the hydrogen evolved are, together, the equivalent due to the current used.

Of course I cannot well, in the limits of a single lecture, more than glance at the principles involved, as I bring to your attention some experiments which serve only to point to the practice of the art.

The electrotyper's bath is in principle the same as that used by the electro-plater. I have here some elegant specimens of his art, and will call your attention specially to some typical ones, and try to give you a general idea of how they are made.

A few years ago, all of the electro-plating and electro-typing of the

country was done by electricity, generated by galvanic batteries. Now, except in the very small way, all electro-plating and electro-typing is done by the use of dynamo-electric machines. The improvements in these machines have been great in a short time. The first dynamo tried for electro-plating by the Elkintons, the great silver-platers of Birmingham, wore its commutator springs out in 20 minutes, and comparatively little of the energy applied to its running was returned as electricity, and the machine was laid aside in a short time, as giving too much trouble and expense. Two or three years ago much trouble was caused to platers by reversal of direction of the current from the machines at times, so that the deposit which had been made was dissolved from the true cathode and deposited upon what should be the anode. This reversal came from the so-called "polarization" of the solution. This polarization takes place in imperfectly working electrolytes, and in others in which the affinities of the metal of the bath and hydrogen are approximately the same. If hydrogen be deposited on the cathode, or if oxygen forms per-oxides on the anode, the cathode and anode become more strongly positive and negative than natural under normal conditions, so that, on stopping the dynamo, a current of electricity comes in the reverse direction from the bath, and, flowing through the field-magnet coils of the dynamo, magnetize it in the opposite, so that when again started it gives rise to a current of electricity having a direction opposite to that which proceeded from the dynamo in the first instance. Various instruments called "polarity protectors" were devised to automatically break the circuit to the dynamo whenever a return current from the bath was about to flow. But these were not infallible; and oftentimes plated work was ruined before the fact of an existing return current was discovered. But now the recent "shunt wound" dynamos avoid this difficulty effectually.

By the batteries for each 108 lbs. of silver, or each 31·75 lbs. of copper deposited, 32 lbs. of zinc were used in each battery cell, besides a large percentage of waste and the expenditure of an equivalent quantity of acid in dissolving the zinc. Much care and trouble attended the use of batteries. They varied much in power during their use, becoming much weaker soon after starting to work. Dynamos have, with the minimum of care, constant power under constant speed of running.

No wonder, then, that the art of electro-metallurgy has taken a new

start, and is receiving a much more extended application than before, considering the ease and economy with which reliable currents of electricity can be generated.

Within a few years after the discoveries of Daniell, Jacobi, Spencer and others, to which I referred in the early part of this lecture, many applications of the new art to industrial uses were proposed. So that we have little that is absolutely new in the suggestions and principles of the art. But it is only since the introduction of the practicable dynamo that we may say we have been able to practice extensively the the broad art of electro-metallurgy.

Here is an electrotype of a page of *The Electrical World*, the weekly journal of electricity which you have seen printed within the walls of the Exhibition Building on a press which is operated by a Daft electric-motor. There is not time to enter into a full description of the process of making this electrotype. Suffice it to say that after the form of type is made up, a mould of wax is made of the face of the type; the surface of the wax is made conductive, and the mould is made the cathode in a bath of copper sulphate solution, in which a copper plate is the anode. Copper is dissolved from the plate and deposited on the face of the wax until of sufficient thickness to be removed from the wax. It then receives a backing of type-metal, cast on the reverse side of the electrically formed copper sheet.

Following the general plan I have just set forth, it is possible to reproduce in copper or other metals fac-similes of many metallic works of art, such as coins, medals, panels, placques, statues and the like. Large articles may be electro-plated with metals for their beautification, preservation, etc. It was, even, early proposed to copper-plate ships electrolytically instead of by the ordinary way. This scheme, so wild in the days of expensive galvanic batteries, may yet be realized in these days of cheap dynamos. No matter now what may be the size of the article to be plated or reproduced in external fac-simile, it may be done if a bath large enough to hold it be at hand. Large cast iron statues are covered with copper or bronze, and lamp-posts, doors, etc., are decorated or imitated.

I have here a large number of electrotypes, kindly loaned me for the purposes of this lecture by Mr. Edward Weston and by the Excelsior Electric Co., whose exhibits attract so much attention in the main building. Here are medalions, ferns, flowers, surfaces showing the grain of wood and leather and the fibre of cloth, and here are speci-

mens of various kinds of laces. All these are from the original artistc production or from nature. Bugs, butterflies, flowers, leaves, fruit and various things too numerous to mention may be covered with copper and then electro-gilt or electro-silvered for ornamental and other uses. A wax form of any object may be made and then coppered and gilded for use. In fact the uses of the art are too numerous to mention, and as useful as they are numerous.

Some of these plates have been made for the purpose of impressing their surfaces on paper or other material in imitation of leather or other materials. Many of the fancy papers and muslins used in book-binding have their beautiful designs stamped upon them by dies made in this way.

I have seen the pieces of stained glass pictures fastened together by electrically depositing copper in the spaces between the pieces, in place of being fastened together by the weaker and more clumsy lead heretofore used. The dark lines, so well known in such pictures, are thus made narrower and less unsightly, while stronger and therefore better. I might go on enumerating until the subject became tiresome; but enough has been said to show the importance of this art in the older lines.

The great present use of the art is in the production of pure metals in processes of separating metals from one another and from various other impurities. In all alloys and admixtures of metals, not useful as such in the arts, the metals less in quantity than the main one of the mixture may be considered impurities, even though they be gold and silver, until they have been made available in the arts by separation from the other constituents of the mixture. Furthermore, there are waste metals which are worthless because of admixture, but which, if separated from each other, are valuable as before. For instance, tin and iron of waste tin plate. Thousands of tons of this waste made yearly may be made valuable by separation, which can be done electrolytically. There are forty tons of tin on a thousand tons of this waste, worth $32,000, besides $10,000 to $15,000 for the iron. A continuously-working apparatus has been used to carry the waste into and out of a bath containing an electrolyte which dissolves and deposits tin alone, leaving the iron free from tin. The so-called galvanized iron, which is iron covered with zinc, may be separated from the zinc in a similar manner.

One of the great industries of the day, fast spreading in the metal-centres of the world, is the purification of metals, and their separation from one another, so that they may be of industrial value, by the means provided in the art of electro-metallurgy. For instance, impure copper has been so treated by the Elkintons, the great electro-plating house of which I have spoken, in the neighborhood of Swansea, in Wales, for several years. Now there are several establishments on the continent of Europe, and two or three in America, where impure copper is refined by electrolysis.

In a few words, the process is as follows, though some slight modifications in the minor details are in vogue. Copper ores are smelted under the usual concentration-smelting processes until brought to the state of purification from iron and sulphur in which it is known as "black copper." This black copper contains somewhat over 90 per cent. of copper, some sulphur, some iron, antimony, etc.; but, as a rule, the valuable impurities are gold and silver.

The black copper is cast from the furnace, in which it is produced, into moulds, so as to assume the form of plates of about one inch in thickness, or less. These plates are suspended as anodes in a bath containing an electrolyte consisting of a solution of copper sulphate. Other plates of very thin sheet copper are also suspended in the bath, but as cathodes. These anodes and cathodes are alternated in relation to each other, so that each two cathodes have an anode between them, and *vice versa*. Their faces are placed parallel and about an inch apart. A current of electricity causes the dissolution of the anodes and the deposition of copper upon the cathodes until the anodes are almost all dissolved. I have here one of these cathodes. It has received a beautiful and thick coating of copper. It is now exceeding half an inch in thickness. It was originally less than one-sixty-fourth of an inch thick. This is *pure* copper, such as the electrician delights in, when his wires and coils are made of it; for its electrical resistance is at the minimum. An abundance of such copper is very desirable to the electrician because the value of his instruments made from it is much increased over those made of the finest commercial copper to be obtained.

This plate, and others shown at the exhibit of the Excelsior Electric Co., in the main building, were produced at the works of the New Jersey Smelting and Refining Co., at Newark, by a dynamo similar to that shown at their exhibit. I have not time to enter into a full con-

sideration of the process in this lecture. In fact, to do so, would make a long lecture in itself. Therefore I must only glance at its main features. Suppose, that besides the main constituent, copper, the anodes contained sulphur, iron, zinc, lead, gold and silver. The zinc, iron and lead are electro-positive to copper, while the sulphur, gold and silver are electro-negative to that metal. Therefore, zinc, iron and lead will displace copper from the electrolyte as fast as they come to the action of the liquid from the removal of the copper during solution. Therefore, if enough of these metals be, during the process, brought into the solution the copper of the electrolyte would be finally all displaced by them. Therefore, the electrolyte gradually becomes more and more impure until, finally, they entirely supplant the copper, for if the current is properly regulated for the purpose of producing pure copper none of these metals are deposited from the electrolyte, no matter how much of them it may contain.

The "properly regulated current" I refer to, is one in which the difference of potential, of which I have spoken, between the electrodes, is below that due to the difference in the values of the affinities of those metals and copper for oxygen and sulphuric acid. Lead, however, though it displaces copper, does not enter into solution in the electrolyte, because the lead sulphate so formed is insoluble therein. So, from time to time, the electrolyte must be purified by processes not necessary to consider here, or made anew.

But the gold, silver, sulphur, antimony, etc., being more electro-negative than copper are not changed, are not dissolved. They remain in their metallic state, but appear on the surface of the anodes as a fine black powder.

When the anodes are nearly dissolved the cathodes are removed and the pure copper thereon is made into suitable commercial shapes by ordinary metallurgical processes. The anode scraps are carefully washed to save the precious residues, and then remelted with more black copper to be again cast into shape for treatment. The residues together with such of the powder as may have fallen from the anodes to the bottom of the baths, are melted with suitable fluxes to produce bars of gold and silver. These bars are then taken to the Government mints or assay offices for separation, coinage, etc. It is probable that this final separation may be yet performed electrolytically, as it is now done in some private establishments, after analogous methods to those I have described.

One of the yearly products of this country is about 140,000 tons of an impure lead, technically called "lead base-bullion." This base-bullion contains, exceeding 90 per cent., on the average, of lead, and from 50 to 500 or more ounces of silver per ton, with oftimes some gold, besides iron, copper, antimony, arsenic, sulphur, etc.

An establishment for the electrolytic separation of these metals, by a process devised by myself, was recently described in *The Electrical World*. The description is a copy of a paper read by me before the American Institute of Electrical Engineers.

I have here samples of the products of the process in its various stages. Here is a pig of base-bullion. It looks like an ordinary pig of lead. It weighs 100 pounds and contains 125 ounces of silver to the ton, besides about ½ ounce of gold. Here are some of the plates cast from the bullion preparatory to treatment, so as to make them into anodes having an extended surface compared to their weight. I have no cathode here. Each one is a very large sheet of thin brass.

Here is a large bottle containing some of the pure lead such as is deposited on the brass cathodes. You will see that the lead is crystalline; something like the lead crystals shown in some of our experiments. You will also notice that the crystals are in a liquid. That liquid is some of the electrolyte. The electrolyte is a solution of lead sulphate in a solution of sodium acetate. You will notice the brilliant faces of the crystals. They will remain thus brilliant for a long time. I have some now kept in the same manner, under the electrolyte, for six years, and they are as bright as ever. This shows that there is no action of the electrolyte of itself on the lead. But when a current of electricity is supplied as in electrolysis the lead is readily dissolved by it.

I have here a muslin bag which is of a size to receive one of these anode plates; and here is one of the plates in a bag. These bags are useful for these reasons: The pure lead is deposited on the cathodes in a crystalline form, and these crystals either drop off, or are swept from time to time from the cathodes to the bottom of the bath. Now, if the residual impurities were allowed equal freedom to drop to the bottom of the bath the separation would be useless. So a bag is provided to retain the residues so that they may not mechanically mix with the purified lead. In the copper separation such a provision is not necessary, because the copper is deposited on the cathode in an adherent and coherent form.

After the anodes have been dissolved the lead crystals are removed

from the baths, and the residues from the bags are separately and suitably treated for commercial purposes.

The principles of this process of refining lead are, that the oxide or sulphate of lead formed at the anodes shall be dissolved by the electrolyte, and that an exact equivalent of the lead dissolved shall be simultaneously deposited on the cathode. Under these conditions no energy is absorbed by the bath other than that used in causing the electricity to pass through the bath.

But if the compounds formed by electricity at the anode be not dissolved, and no metal be deposited on the cathode, then energy will be absorbed. This energy so absorbed may be given off as electric current under favorable conditions. We would have in a bath so constituted as to insure these latter conditions, a so-called storage battery of electricity. These facts I noted and put into practice in the spring of 1878; and then made a large storage battery on these principles and used it practically.

I have here, on this stand, a strong battery cell, kindly loaned to me for this lecture by the Faure-Sellon-Volckmar Co. It consists essentially of lead anodes and lead cathodes immersed in an electrolyte consisting of dilute sulphuric acid. Exactly what takes place, chemically speaking, in a storage battery, authorities differ about. Therefore I will only say that when electric current is passed to a storage battery something is decomposed for which no equivalent composition is made. Therefore, as we have seen, energy must be absorbed; and when the proper circuits are provided the materials so separated by the decomposition recombine, and in so doing give up the energy they had absorbed electrolytically, as electricity.

As may be deduced from the facts and principles I have set forth, energy may be stored up, so to say, by electricity, in baths of various materials, wherever the energies of combination at the anode and cathode differ. This field of research is barely discovered, and thorough exploration of it may lead to the discovery of valuable facts for use.

The phenomenon called polarization, to which I have referred, belongs to this field. Polarization is to be avoided in the electric transferrence of metals, for its existence necessitates the expenditure of costly energy. It may be avoided in some measure, and in many instances almost entirely, if the electrolyte be properly constituted, by keeping the molecules of the substances which take part in the operation in constantly appropriate relation to one another. The electro-

negative constituent of the electrolyte must be in constant contact with the electro-positive anode; and the electro-positive constituent of the electrolyte must be in constant contact with the electro-negative cathode. Otherwise, other and improper constituents take part in the operation and energy will be absorbed or uselessly expended. To avoid this condition, which takes place when the electrolyte is motionless, owing to the decrease of the amount of the proper constituents at the electrodes due to the action itself, a constant circulation of the electrolyte must be kept up; and the more rapid this is the greater the speed of the electrolysis, or the less the strength of the electrolyte requires to be.

But I see that my allotted time has been much exceeded and therefore I must bring my remarks rapidly to a close. I have been able only to glance at some of the principles and practices of this great art which may be said to be scarcely in its infancy. As I contemplate its future I see in this great means of producing and utilizing a form of energy which we call electricity, a great aid not only to the metallurgist but to the chemist in his researches and analyses. We have seen that by its aid we determine the affinities of one material for another. We may compose and decompose many compound substances. The chemist's art is but this. I see that he can produce his metals and his salts by this action, and in many cases much more cheaply than by the various processes of substitution he now employs. And before many years we will not only see extensive electro-metallurgical establishments for the production and working of metals, but we will also see, side by side with them, their legitimate branches, electro-chemical establishments for the production of chemicals, dye-stuffs, etc.

But a short time ago it would not pay to do these things by the expenditure of zinc and acid. Now the grandest concrete production of the physicist, the dynamo-electric machine, furnishes us with means for conserving energy to industrial purposes, marvellously, effectually and cheaply. I thank you for your kind attention.

JAPANESE COLONY IN GERMANY.—Some Berlin capitalists are about establishing, near that city, a Japanese colony of forty workmen and their families, in accordance with the plans of a Japanese architect. There will be workmen in metals and in lacquer, ceramists, painters, enamelers, silk weavers, etc., all working according to the methods of their native land. The public will be admitted to study the various processes employed by the workmen.—*La Nature*, May 31, 1884. C.

THE DIVINING-ROD.

BY ROSSITER W. RAYMOND, PH.D., New York City.

[A lecture delivered at the International Electrical Exhibition, September 18, 1884.]

(Concluded from page 18.)

I condense from M. Chevreul's book the following list of the principal authors on the subject, for the period now under consideration.

Dr. Chauvin of Lyons (a letter to the Marquise de Senozan, dated September 22, 1692, published in the brochure *Superstitions anciennies et modernes*, Amsterdam, 1733; also in an appendix to the 2d edition of Lebrun's *Histoire critique des pratiques superstitieuses*).

Dr. Pierre Garnier of Lyons (a letter to M. de Sève, published November 10, 1692, at Lyons). This, like the letter of Dr. Chauvin advanced the corpuscular hypothesis.

Two anonymous letters concerning the divining-rod, published in the *Mercure* of January and February, 1693. The first combats the corpuscular hypothesis; the second argues that, although this explanation is to be rejected, there is, nevertheless, nothing supernatural, magical or diabolic about the phenomena, and that they are probably to be referred to physical causes as yet unknown.

M. de Couriers, a blind man and thorough partisan of the divining-rod (a letter in the *Mercure* of March, 1693).

M. L. de Vallemont, priest and doctor of theology (*Physique occulte, ou Traité de la baguette divinatoire et de son utilité pour la découverte des sources d'eau, des minières, des trésors cachés, des voleurs et des meurtriers fugitifs*, Paris, 1693, 12mo. 608 pp.). The argument of this book has been summarized above. Its purpose was to diminish the category of "occult" things by showing that the phenomena of the rod, like those of magnetism and electricity, were explicable by the physical corpuscular hypothesis.

Two letters published in the *Mercure* for April, 1693, by order of the Prince de Condé. One is anonymous; the other is addressed by M. Robert, *procureur du roi*, to Father de Chevigny. These are the documents which record the failures of Aymar; and the second concludes as follows: "His Serene Highness desires the assurance to be given to undeceive the public, that the rod of J. Aymar is nothing but an allusion and a chimerical invention. These are the Prince's words."

Father Lebrun (*Lettres qui découvrent l'illusion des philosophes sur la*

baguettes, et qui détruisent leurs systèmes, Paris, 1693; also *Histoire critique des pratiques superstitieuses qui ont seduit les peuples et embarrassé les savants*, Rouen and Paris, 1702). These publications have been alluded to above. The letters comprise an interesting correspondence among Father Lebrun and three of the foremost *savans* of France, Father Malebranche, the abbé de Rancé (the celebrated abbé de la Trappe), and the abbé Pirot, chancellor of the University of Paris. Lebrun (writing before the Lyons murders) narrates the alleged powers and performances of the diviners of Dauphiny, and asks Malebranche what he thinks of the matter. The latter, reasoning acutely on the data offered, decides that, as to physical objects (*e. q.* springs) if the action of the rod is real, water on the surface must agitate it more powerfully than water underground, also that it cannot be possible by any natural law to distinguish between the action of a small spring near the surface and a larger spring lying deeper. As to moral effects (discovery of murderers, missing landmarks, etc.), he concludes that if the rod really does this without fraud, it can only be from a supernatural cause (presumably demoniac) and that the use of the rod is therefore to be condemned. Lebrun rejoins, agreeing with this view as to the moral effects, but suggesting the corpuscular hypothesis as to material objects. A second letter of Malebranche declines to yield this point, and positively ascribes the whole thing to the devil. Meanwhile, the abbé de la Trappe consulted by Malebranche, and (like the latter) assuming for the sake of the argument, but not accepting fully the reality of the phenomena, says the discovery of murderers, etc., must be ascribed to Satan, but the physical effects may be the result of a physical cause. Nevertheless, the use of the divining-rod should be discouraged altogether on religious grounds. Chancellor Pirot takes the same position, saying that the curés should forbid this practice as unlawful.

In his *Histoire Critique*, Father Lebrun gives a large number of instances in which the divining-rod has failed. He cites the provost of the Isle of France, who testified that he had often employed experts with the rod, both to detect criminals and to discover springs, and had never found one in whose hands the instrument was not "often variable and very often false." He shows the fundamental contradiction between two schools of practitioners, one of which declared that touching the rod with the same substance as the hidden substance which was causing it to move, would stop the motion; while the other declared

that this proceeding augmented the motion. The conclusion of the argument is, that the phenomena of the rod (which Father Lebrun appears to believe are sometimes free from conscious imposture) are due to an intelligent cause of some kind, and that this cause must be satanic.

Father Ménestrier (*Indications de la baguette pour découvrie les sources d'eau, les métaux cachés, les vols, les bornes déplacées, les assassinats*, etc., published at the end of the author's *Philosophie des images énigmatiques*, Lyons, 1694). This author takes the same view as the preceding.

M. Baritel (*La Verge de Jacob, lou 'art de trouver des trésors*, 1693). The translation of this book by Thomas Welton has been already mentioned. The author appears to hold the corpuscular theory of the abbé Vallemont, with the addition (which I do not find in any of the views of Vallemont's book), that he ascribes the capacity of different men in the use of the rod to the effect of the planets under which they were born, and defines this effect to consist in opening the pores of some more than others, and filling some more than others with "active particles," which being crowded out through the aforesaid open pores by the intrusion of exterior particles (from springs, metals, murderers, stolen goods, boundary lines, etc.,) powerfully affect the rod. Whoever has from his favorable stars both particles and pores galore, can discover with the rod anything he reasonably seeks. But he who has "only plentitude of particles with closed pores," will be sensitive to certain things only, to wit, such as move him most strongly, because the particles emanating from them violently eject *his* interior particles in spite of his less abundantly perforated epidermis.

The condemnation expressed by so many ecclesiastical authorities and by the Inquisition (October 26, 1701) undoubtedly checked the use of the divining-rod for moral purposes. At least we hear little of such applications in the eighteenth century. But believers in the rod were still numerous, and practitioners abounded, particularly in Dauphiny. The discoveries of Galvani put into the hands of the crude science of the day the materials for a new hypothesis, which was first applied to the so-called hydroscopes or water-diviners. One of the most celebrated of these, Bartholemy Bleton, was born in Dauphiny in 1750, and in 1780 was called to Lorraine by Dr. Thouvenel, who wished to study a good specimen of this art. The doctor, like his predecessors a hundred years before, tried credulous experiments and asked questions in abun-

dance, and obtained a mass of supposed facts, out of which he immediately made a book, published in 1781, and called *Mémoire physique et medicinal montrant des rapports évidents entre les phénomènes de la baguette divinatoire du magnetisme et de l'électricité.* It would be useless to give the voluminous details of his investigation. The following points are, however, especially noteworthy. In the first place, Bleton apparently did not profess to discover immaterial qualities or facts, but chiefly confined himself to the detection of running water. In the second place, he frankly avowed that the rod possessed no power in itself by virtue of its form or material, and that it was merely an index, outwardly exhibiting to the spectators his inward feeling. This feeling the doctor declared to be a tremor, attacking first the diaphragm and communicating itself through the body and hands to the rod. In the third place this tremor was found by Dr. Thouvenel to be weakened, though not destroyed, when Bleton was on a tree or ladder or another person's shoulder, instead of the ground, or when he touched electrified substances; but the tremor and also the movement of the rod were completely stopped when Bleton was insulated from the ground. Upon facts of this kind he based his electrical theory. I remark, by the way, that the observations and the theory of Mr. Latimer, in his recent work on the divining-rod, already mentioned, recall in a striking manner the performances of Bleton and the theory of Thouvenel. Mr. Latimer claims to have made the new discovery that the effect of the divining-rod is destroyed by insulating the practitioner, as for instance, by placing him upon a platform supported by glass bottles. If he had known how thoroughly this claim had been examined and refuted, almost exactly one hundred years ago, he would have had less faith in its novelty and value.

Thouvenel's book made no little sensation, and in 1782 Bleton was called to Paris, where a remarkable series of experimental tests were applied to him. A newspaper report of the day declares that in the presence of many thousands of spectators he followed a subterranean aqueduct in the garden of the Luxemburg for fifteen thousand yards without a mistake. The chief engineer of the water-works is reported to have said that the trace was so accurate, that if the maps of his office had been lost, Bleton's foot-steps would have constituted a complete survey to replace them. It is just possible that the *Journal de Paris* was tempted to make a sensation of this case, and it is also quite possible that a keen observer might notice indications other than those

of his own diaphragm, by which he could follow the line of buried pipes. A large number of experiments, more calmly reported, certainly do not sustain the enthusiasm of this account. It was found, for instance, that Bleton often passed over running water, when blindfold, without noticing it; and that when taken several times over the same course he would not point out accurately each time the spots which he had previously marked. For example, of sixteen points once indicated, he recognized with the rod on the second round but eight and missed the other eight. A single point to which he was repeatedly brought blindfold, he indicated three times and missed three times. Of seven channels of running water which he was made to cross repeatedly, he indicated one once in four times, another once in four times, and another once in three times, while still another, which he crossed in two spots, affected his diaphragm at one crossing, and not at all at the other. The insulation experiment was repeated by a physician at Paris. As a point where Bleton's rod was powerfully affected by alleged subterranean water, he was mounted upon a stool with glass legs, and immediately the rod ceased to be affected. When the stool was removed, however, and he stood upon the ground, the rod resumed its sensitiveness. But Dr. Charles, who conducted this experiment, took occasion, while Bleton stood upon the stool, to bring the top, without his knowledge, into electrical communication with the earth by means of a good conductor, thus destroying the insulation completely, though the hydroscopist supposed it still to exist. Under these circumstances, the rod remained inactive, and the destruction of insulation did not produce the slightest result. This was declared at the time to be a proof of Bleton's charlatanry; but, as we shall see hereafter, it is equally consistent with the hypothesis of unconscious mental and muscular action.

As a final test of Bleton's capacity as a hydroscopist, he was taken blindfold into the new church of Saint Genevieve, where there was known to be no water for one hundred feet below the floor, the vaults, foundations, etc., actually extending all that distance below. Here he professed to discover at numerous points large and small streams of water. Thouvenel subsequently asserted that his *protagé* had been affected by currents of damp air circulating in the cellar, but this explanation was universally considered as a desperate attempt to maintain a theory already brought into discredit by experimental tests. Bleton, however, though he ceased to be seriously respected by impartial scien-

tists, continued to receive much attention, and to do a thriving business, both in Paris and subsequently in the provinces. Here, however, he no longer worked blindfold or professed to see with his diaphragm. He proceeded, like the ordinary water-diviners, with open eyes, studying all the natural indications, and coming to his decisions with abundant leisure; and under these circumstances it is beyond doubt that he rendered many valuable services to landed proprietors by successfully locating wells. In many cases, however, he failed entirely, and it is reported that even in those in which he succeeded, he was seldom right as to the depth at which water would be found or the quantity which would be obtained. It should be mentioned that in Dauphiny, where Bleton discovered a large number of springs, he was regarded with an esteem never given to Aymar and some other famous hydroscopists. In other words, the people who knew most about the art of discovering water, pronounced Bleton to be a real expert, while they believed Aymar and Prarangue (of whom a word presently) to be more or less charlatans. A review of all the facts leaves little doubt that in Bleton's case there was an unusually large proportion of the skill of the prospector, combined with rather less than usual of the mysterious claims of the wizard.

Concerning Jean Jacques Parangue, mentioned above, it will be sufficient to say that he was born in 1760, near Marseilles, was said to have been peculiarly sensitive as a child to the presence of subterranean waters, and became famous as a hydroscopist; but he used no rod at all, and the scientific theory advanced by his friends was one of clairvoyance. His eyes were described as very peculiar, and it was asserted that he saw water through rocks, earth or masonry, but, strangely enough, not through wood, crystal or glass. Like Bleton, he often deceived himself as to the volume and depths of the springs he discovered.

Dr. Thouvenel never saw Parangue, but defended him against the incredulity of the physicists and undertook to show that the phenomena of clairvoyance even was merely a case under his electrical theory. According to his explanation the delecate nerves of the eyes were affected by the electrical currents traversing the body, and therefore the clairvoyant really experienced the sensation of vision by an internal, not an external excitation. Those who have read the admirable treatise of the late Dr. Clarke upon *Pseudopia* will notice with interest that in this case Dr. Thouvenel, explaining imaginary facts by an

untenable hypothesis, nevertheless came very near a true physical theory of visions.

The worthy doctor emigrated at the time of the French Revolution, and carried with him to Italy another Dauphinese hydroscoped named Pennet, whom he exhibited from city to city in support of his electrical theory. Pennet professed to find with his rod not only water, but buried metals and coal. I will not go at any length into the experiments. Some of them were striking and successful, and impressed even such *savans* as Spallanzani, more or less predisposed to expect discoveries in the new domain of animal magnetism. In many other cases, however, the experiments failed. For instance in a trial of three days, at Padua, before a commission of *savans*, Pennet promenaded for two hours on the first day in a garden in which had been buried at different points, four metallic masses and a thousand pounds of coal. He could not find the metals at all, and only after much difficulty indicated the coal. On the second day his ill success was equally marked. Finally, on the third day, of three metallic deposits he failed to find the first, came pretty near the second without exactly hitting it, and found the third. The area covered by the search was only 840 square feet. Upon this test, Spallanzani revoked his favorable opinion. But at Florence, as reported by M. Bilot (*Mélanges scientifiques et litteraires*, 1857, t. ii., p. 80), though I do not know on what authority, Pennet was so completely disgraced as to render worthless all evidence furnished by his career. A walled enclosure was prepared for experiment. It contained ninety small divisions in five of which metals had been hidden. Dr. Thouvenel having discovered that wet weather hindered success, the experiment was delayed until after eight dry fine days, and it was then fixed for the following day. During the night which intervened, Pennet climbed by means of a ladder into the enclosure. A suspicious person who was watching the ground removed the ladder, and whatever the divining-rod could show, it was unable to show the prisoner the way out. This adventure, being made public, destroyed the credit of Pennet at Florence. Dr. Thouvenel could not deny the fatal fact, but, with true loyalty to science, declared that Pennet's moral defects had nothing to do with his physical faculty. It is not only fair to add that no such passage as this is cited from Dr. Thouvenel's works.

Numerous hydroscopes soon appeared in Italy, and a vigorous discussion of the subject followed. One of the latest celebrated experts of this class was Campetti, who was called to Munich in 1806 for sci-

entific examination. One of the writers of this period, the Abbé Amoretti, himself a member of a family containing many hydroscopes, makes the significant assertion that the sensation experienced by the holder of the divining-rod is one of heat or cold. But the name of Amoretti recalls the fact that he was one of those who revived and continued the discussion of "the magic pendulum."

The earliest mention of this apparatus, according to M. Chevreul, is found in the work of Ammianus Marcellinus, the last of the Latin historians, who died A. D. 390. In an obscure passage (lib. xxix., cap. 1), giving the confession of one of the conspirators against the Emperor of the East, this author describes in the words of the conspirator, the ceremonies adopted by the band to discover the name of the Emperor's predestined successor. Among these was the use of a ring suspended by a fine thread over a disk, around the edge of which, at equal intervals, were the letters of the alphabet. The ring in its oscillations pointed out successively the letters T, H, E, O; whereupon, without further continuing the inqniry, all perceived that Theodorus was the one designated by destiny.

Father Schott mentions the pendulum in his *Physica curiosa* (1662), already alluded to in this paper.

In the latter part of the eighteenth century, and at the beginning of the nineteenth, several scientific men were attracted to this phenomenon. Albert Fortis, (*Mémoires pour servir à l'historie naturelle et principalement à l'oryctographie de l'Italie et des pays adjacents*, 1802), Prof. Gerboin of Strasburg (*Recherches expérimentales sur un nouveau mode de l'action électrique*, 1808) and Prof. Ritter of Munich (see his report in the Tübingen *Morgenblatt für gebildete Stände*, No. 26, January 30th, 1807) were among the number, as well as the Abbé Charles Amoretti, librarian at Milan, to whom I have already alluded. As this mention of the pendulum is in the nature of the digression, though (as will appear) not without pertinence to my main argument, I content myself with an abstract from Ritter's article. He says:

"Take a cube of pyrites, native sulphur or any metal. Size and form are indifferent. We may use, for instance, a gold ring. This body is attached to a piece of thread, quarter to half an ell long. This is held pinched between two fingers and suspended vertically, all mechanical movement being hindered. It is best to wet the thread slightly. In this condition, the pendulum is held over or close to a vessel full of water, or over any metal, as a piece of money or a plaque

of zinc or copper. The pendulum insensibly assumes elliptical oscillations, which form themselves into a circle, becoming more and more regular. On the north pole of the magnet, the movement is from left to right; over the south pole, from right to left; over copper or silver, as in the former instance, over zinc or water, as in the latter. . . . . Over an orange or an apple, on the side of the stem, the move is the same as over a south pole; on the opposite side, as over the north pole. The same difference in polarity is shown by the two ends of a fresh egg. It shows itself still more strikingly in the different parts of the human body, the head acting upon the pendulum like zinc, the sole of the foot, like copper; forehead and eyes, north pole; nose and mouth south pole; chin like the forehead; and so on, with all parts. The palm and the back of the hand act in opposite senses. The pendulum will move over every point of the finger, and even over the fourth or ring-finger, but, in that case, in an opposite direction. This finger has also the faculty of arresting or diverting the movement of the pendulum. It needs merely to be placed alone upon the table used in the experiment"

So much for the outline of Ritter's statement. He was at this time occupied with Campetti, above mentioned, and naturally he brought together in his thoughts the divining-rod of Campetti with the pendulum of Fortis (Fortis had experimented with it, and it was often called by his name, in consequence; but his death in 1803 deprived Ritter of his advice and aid in further tests).

Competti was a young peasant from the borders of the *Lago di Garda* who had seen the performances of Pennet, Dr. Thouvenel's last *protegé*, and had found himself possessed of similar powers. Not only Ritter, but Schelling and Franz Baader examined him. The opinion expressed by Ritter was that the divining-rod is simply a double pendulum, requiring to set it in motion, a force greater than those which move the pendulum. Ritter wrote this after consultation with Amoretti and others; and after either he or Amoretti had visited and consulted, at Padua, the great Volta.

But Prof. Gerboin carried his scientific study of the pendulum to a much greater extent. His book contains in 356 octavo pages the records of 253 experiments, and a most elaborate theory of "organo-electric force," in its different qualities, expansive, compressive, passive perturbatory and active perturbatory. The simplest actions of

these qualities may be indicated thus—to condense from the professor's somewhat verbose description:

By virtue of the *expansive* quality, which resides most abundantly in the thumb and fore-finger, a pendulum held between these two is caused to describe with its centre of gravity a circle. The *compressive* quality, belonging characteristically to the middle finger, will not permit this motion, or will stop it—as when a highly *compressive* man touches the hand of an *expansive* man, which is holding the swinging pendulum. Contact ceasing, the movement recommences. The *passive perturbatory* is a high degree of expansive, and the *active perturbatory* in like manner a powerful *compressive*. The possessor of the former, if, while holding a pendulum he is suitably touched by one of the first or second class, will find the pendulum, if at rest, to start backward; and if in motion already, to reverse its motion. The fourth class is, like the second, negative in its action. Persons exercising either the compressive or the active perturbatory quality cannot cause the pendulum to oscillate; they can only counteract or reverse its oscillations in the hands of others.

Considering that the author goes on to formulate the permutations and combinations of these qualities of force, their relations to the different fingers, and to a long list of organic and inorganic bodies, I may be excused from following further his intricate and obscure system. Elaborate as it is, the whole structure is absolutely baseless; and constitutes a capital example of what St. Paul denominated "science, falsely so called." Its vast array of worthless experiments are merely so many ciphers in a row, with a decimal point instead of a unit at the head. When the distinguished chemist Michel Eugène Chevreul (long the chief of the Gobelin tapestry-works, and the author of a well-known book on Color, as well as other important works) took up the subject in 1812, he was not long in discovering that when the eyes of the operator were blindfolded, so that neither his will nor his thought could consciously or unconsciously affect the movement of the pendulum, the data, arguments and conclusions of Fortis, Amoretti, Ritter and Gerboin, the organo-electric force, with its qualities *expansive, compressive* and *perturbatory;* the south poles and north poles, the classifications of the universe thereby;—in short, the entire science, bag and baggage, disappeared!

Gerboin had pronounced the action of the divining-rod to be a case of *passive perturbatory.* Chevreul, as we shall see, put both the rod

and the pendulum in a new category. But before proceeding to state his theory, I will devote a word or two to the evidence presented in our own country.

It is safe to say that most of it, like most of the evidence of the past, is open to the suspicion of at least an alloy of deception. Men who make money out of their reputed skill with the divining-rod and who could not make as much money or advertise themselves so widely if they claimed only a high degree of skill as prospectors, will almost inevitably ascribe to the rod what is due to other means of inquiry; will explain away failures, exaggerate successes, and not establish or execute or permit really thorough and sincere experiment. The most distinguished expert in this art on the Pacific coast has been repeatedly made ridiculous by the result of test experiments. On one occasion, as I learn from an eye witness, who also reported the circumstances to the *Mining and Scientific Press* of San Francisco, this diviner was permitted to inspect a metallurgical laboratory, which always contained a large amount of gold, either in bullion or coin. After this inspection he was brought (blindfold) again into the laboratory, and assured that no coin or bullion had been removed. Under these circumstances he was requested to find the metal with his rod. The coin had all been put in its natural receptacle, the fire-proof safe; and the bullion had been fastened with wire to the under-side of a writing table. The operator found neither of them, though the point of his rod was frequently within an inch of thousands of dollars. He had probably suspected a trick, and he declared that the gold had been removed. When the bandage was again removed from his eyes, and the coin and bullion shown to him, he claimed that his rod had been diverted by the immense amount of treasure in a bank half a block distant! There have also been operators in California claiming to be natural magnets, and not using the rod; but they are not known to have accomplished any better success. One of these natural magnets was employed to trace a lost vein for a mining company at Grass Valley, the mine of which had been at one time the most productive in California. Under his direction the company cut for many hundred feet, at an expense of $30 to $40 per foot, through tough serpentine rock, and found nothing. Not only are these belts of serpentine at Grass Valley well known to be barren in general, but this particular belt was actually exposed in a cross-section, parallel to this expensive underground cross-cut

only one-eighth of a mile away. The persons most familiar with the mining districts of the West declare that in Grass Valley, and elsewhere, the divining-rod has accomplished nothing of practical value. It is very recently announced by telegraph from Tombstone, Arizona, that a large body of ore has been found at a considerable depth, under a spot indicated by the "hooda-stick" (which, I suppose, is some sort of divining-rod) in the hands of a common workman. I need hardly say that such a discovery proves nothing. It would be of course presumptuous for me in the absence of information as to persons and circumstances to criticise this most recent case, but I cannot forbear saying that nothing is more common in experience of mining superintendents than the discovery of ore-bodies by workmen, who have carried for a long time the secret knowledge of their existence. Most frequently it occurs when a mine seems to have been exhausted, or at least the superintendent does not know where to look for ore, and finally leases some portion of the ground to miners who, by a good luck that would be surprising if it were not so easily explained, go straightway into a *bonanza*. It is not always, however, the certain knowledge of the existence of an ore-body observed by workmen and kept secret with a view to future profit, which guides these practical explorers. Often it is their great familiarity with the indications of the ground, and sometimes let me add, the ignorance and pride of the manager himself co-operate with this result, by leading him to pursue some erroneous theory of exploration, and to refuse the advice of practical men. The so-called instinct of Mexican miners for finding ore, exhibited particularly in such irregular formations as those of the quicksilver mines of New Almaden, is, indeed, an unconscious practice of an unwritten science.

The scientific explanation of the movement of the divining-rod was given by M. Chevreul, in a letter to M. Ampère, published in 1833 in the *Revue des Deux Mondes*. This letter contained an account of the experiments made by the writer in 1812, more than twenty years before, with the pendulum. Finally, in 1853, M. Chevreul having been appointed by the Academy of Sciences upon a committee to examine a work on the divining-rod, wrote a report on the subject, including the "exploring pendulum" and the then novel wonders of "table-tipping."

This report was published in 1854, under the title *De la Baguette Divinatoire, du Pendule dit Explorateur, et des Tables Tournantes, au*

Point de Vue de l'Histoire, de la Critique et de la Méthode Experimentale. It is worthy of notice that this venerable *savant* is still active at the age of ninety-seven; only the other day, he spoke before the Academy, referring to a paper he had presented to that body, if I remember correctly, seventy years ago!

Chevreul ascribes the movement of the rod, apart from cases of deliberate deception, to minute, unconscious, muscular movements; and these are caused, he thinks, by the imagination or intuitive or unconscious decision or expectation of the operator. An impression that the rod will dip at a certain point, or a wish that it would, or even, in some minds, a fear that it may do so, are all effective causes of the peculiar muscular movement. Stories describing motions of the rod so violent as to strip the bark from it, in spite of the resistance of the holder, do not disprove the above theory. The position of arms, hands and fingers usually prescribed for the holding of the rod, as explained in the beginning of this essay, is one in which it is not easy (though not impossible) to produce by conscious effort the peculiar movement referred to. But it is also one in which skillful effort, if employed, may be easily disguised; and, finally, it is one which invites muscular cramps, and produces muscular torsions and involuntary movements, not to be resisted successfully without a change of position. Under these circumstances a man might easily twist the bark from a willow-stick, and yet fancy he was trying not to do it.

In concluding this survey of the subject, I shall take a somewhat wider view than M. Chevreul, and my remarks, though based on his theory, should not be received as representing it.

From the mass of testimony, good, bad and indifferent, the following propositions may be safely deduced:

1. The material, consecration, astrological relations and ritual formalities of the rod are entirely irrelevant and indifferent to its efficacy. This disposes at a stroke of nine-tenths of the science which the Middle Ages so laboriously accumulated on the subject.

2. The rod itself is entirely inert, unless in the hands of a human operator; and according to the declaration of the most famous experts, such as Aymar, Bleton, Amoretti, and many others, and a whole school of diviners who do not use the rod at all, it is merely an index, revealing and magnifying in visible results the peculiar inward sensations of the diviner.

3. The favorite and most convenient form of the rod (λ) is one which promotes involuntary movements and also permits deception.

4. The involuntary minute musclar movements may proceed either from the causes enumerated by Chevreul, or from a truly and purely physical sensation. To this I will presently recur.

5. The uses of the rod for discovering moral qualities, re-locating missing landmarks, tracing stolen property, prophesying the future, or even (as in the 17th century was the case) selling the orthodoxy of theological dogmas, will not now be seriously defended by any one. They belong to charlatanry and superstition.

5. The agency of demons we may also set aside, as a view outgrown if not disproved. The pious Jesuit Gaspard Schott (1662), who held this view, was, as we have seen, shaken in his faith, though not convinced, by testimony showing how often the rod failed to act, or gave unreliable indications. He half admits that if Satan were at the bottom of it, it should work better. As an instrument of divination, it is unworthy of the devil! But, it might have been rejoined, that, as a means of perplexing and misleading mankind, that distinguished expert could scarcely have improved upon it.

As old Albinus (*Das entlarvte Idol der Wünschelruthe*, 1700) quaintly says:

"Ich achte, dass kein verworrener Ding in der Welt zu finden als das Wünschelruthen-Wesen, denn was Einem recht und tauglich ist, das ist vielen Anderen wieder unrecht und untauglich, dass aus solcher grossen Confusion nicht viel Gutes zu prãsumiren ist."

[I ween, that no confoundeder thing is to be found in the world than the divining-rod business; for whatsoever is right and fit according to one, the same is wrong and unfit according to others; until there is no good to be presumed, out of so great confusion.]

7. The application of the rod to the discovery of metals, coal, buried treasures, etc., is shown abundantly to be chimerical. The rules and methods, as well as the asserted performances of its professors, contradict each other; and innumerable failures and exposures have justly covered with ridicule their pretensions.

8. The transparent humbug of locating wells with the rod, to strike oil at depths of from a hundred to thousands of feet, needs no comment. In this case there are positively no signs by which a given *spot* can be selected. The experience of neighbors may show a certain area to be probably productive; and within that area a certain line may be

inferred, sometimes, to be the line of a productive channel. But if a keen observer, having gone so far, professes to select a point on that line, he is simply betting on his luck; and, as carried on in Pennsylvania, the bet is a safe one for the oil-smeller, who gets a handsome fee if he wins, and loses, in the opposite event, nothing but an hour or two of time.

9. The case is somewhat different with the discovery of springs, and (since ore deposits always have been and often still are the channels of springs) of ore-deposits. Here we have much stronger and more abundant evidence in favor of the rod; and here, in my judgment, there is a residuum of scientific value, after making all necessary deductions for exaggeration, self-deception and fraud. Keeping in mind that the rod is merely an index to the minute muscular movement, and that this movement may have a mental or a physical cause, let us consider (putting aside at once all cases of deliberate deception) the following facts:

There is undoubtedly a practical science of discovering mineral deposits and springs. The most skillful prospectors can scarcely explain how they decide upon the place where they dig; and yet, though they are by no means always successful, it is certain that they are more successful than the inexperienced. The books from Agricola down, give rules and signs; but the practical explorer is unacquainted with the books. He has a science of his own, which affects his mind, without conscious reasoning, by the principles of association and memory. He recognizes in a new locality the tokens that he has become accustomed to associate elsewhere with a rich gulch, or an abundance of pay-quartz. Perhaps he never took conscious note of them; yet their recurrence affects his judgment. This practical skill is almost unerring within narrow limits. Under new conditions, it breaks down. Some of the most absurdly foolish gold-mining enterprises I have known, have been set on foot by old California miners, who, returning to their former homes east of the mountains, have said at once of some ravine or hillside, that it was "just the place for gold." In like manner, certain omens and signs from Cornwall have been carried around the world by Cornish miners. But whatever the errors of practical prospectors, the noteworthy point is, that in localities with which they are familiar (or in other localities where the conditions are the same) they come swiftly, surely, and without conscious reasoning, to impressions and decisions. A decision of this kind would probably,

in a man of suitable nervous organization, affect the muscles already constrained by holding a divining-rod, and the minute muscular movement or inward sensation might be unconscious.

The case is still plainer with regard to the discovery of springs. Everybody knows that Indians in our desert West can find water where most white men cannot; and the experienced frontiersman has learned the art from the savages. The conformation of the surface, the tracks of animals, above all, the presence or absence of certain plants, are his guides. In regions where the finding of water within a few feet of the surface is a question of life or death, it becomes a science very rapidly. The location of artesian wells is a different matter. Science will do that in a general way; but science will not determine a difference between one spot and another, ten or twenty feet away, the geological and topographical conditions being alike in both; and the selection of one of two such points as better than the other for a deep well, is purely a piece of imagination or deceit. It must be remembered, however, that the diviner has in such a case an easy task. If possessed of sufficient practical judgment to decide that a certain area or line would probably be suitable for boring; he is pretty sure to be safe in selecting any point of it. But this, it will be seen, is very different from the unconscious skill which points out in the dry *arroyo* the very spot where water will be found in half an hour's digging.

In abundantly watered regions like New England, it is perfectly well known that the springs follow under or through the soil and above the bed-rock, more or less defined channels. A well may be dug at one point without success, and a subsequent attempt a few yards away may be successful. The superficial signs of these water-courses are often subtle, and they are little studied by the inhabitants in general. It is not necessary that a farmer, who will want to locate a well once in his lifetime, should know the signs of water, as a ranchman or *vaquero* must know them. Hence, men who are keen observers (in many instances, finding profit in the business), get impressions, amounting to a local science, of the "lay" of the rocks, the general courses of the springs, the differences in surface vegetation, the earlier or later greenness of grass, the presence of particular grasses and shrubs, the ascent of local vapors at sunrise, the behavior of frosts, in short a hundred minute tokens which betray the presence, even at considerable depths, of a water-channel, and the point at which it comes nearest to the surface. The unconscious judgment of such an expert

may decide upon a given spot over which he walks; and while he could undoubtedly come to this conclusion without having a rod in his hand, I am willing to admit seriously that the rod may help him make up his mind by emphasizing for him his own slightest tendency to a decision. It should be remembered here that even Bleton, the greatest of all the hydroscopists, generally used to go (if permitted) many times over a piece of land before finally locating a well, and often disregarded the first intimations of the rod. In other words, unless he felt sure, every time he crossed a given spot, that it was a good place to dig, he did not rely upon his first sensation or impression. Moreover, neither he nor any other hydroscope has ever accurately divined, except on an occasional lucky guess, either the distance from the surface or the quantity of a subterranean spring. Yet a very large spring, or one very near the surface, appears to have had, usually, a relatively greater influence upon hydroscopes.

This brings me to the final inquiry, whether there may not be, apart from unconscious skill or judgment, a purely physical effect produced by a subterranean spring upon a person walking over it. Electrical theories on this point were only possible in the days when the laws of electricity were little understood. We know now that the earth is a vast conductor, and that the tension of its currents is consequently so low as to be reckoned as the zero of the electricians' scale; hence, that no perceptible electrical current can leave a particular bit of the earth to pass through a human body and return. For this purpose analogies between rock-contacts or fissure-veins and the voltaic pile are inapplicable.

But the effects of moisture and temperature upon the nerves are often striking; and here, I think, is a matter which writers on the divining-rod have generally overlooked. The distance at which animals will "scent water" is very great. Their faculty is supposed to consist in great sensitiveness to temperature and moisture. The quickness with which some people "catch cold" on the slightest exposure to dampness—particularly of the soles of the feet—is also a familiar phenomenon. Now it is curious that among the most puzzling of the well-authenticated accounts of the divining-rod are related instances in which women, unacquainted with its use, and not expecting it to work in their hands, have found it to dip without their conscious help, over spots previously or subsequently shown to contain springs.

Here I would recall the remark of Amoretti, that the sensation of

the diviner is one of heat or cold. These two are not easily distinguishable when minute and transient. What we call a chill includes both. Is it not probable that a single unconscious chill may be the physical result to certain sensitive persons, of walking over a spring of water or a belt of rock or soil kept by running water cooler than the adjacent rock or soil, or a spot of surface made by the same cause damper than the surrounding surface. That these causes exist, is beyond doubt. Thermometrical measurements have not been made; but the way in which grass grows and snow lies and frost settles and vapors rise over springs, is due to the temperature and moisture of the ground in such places. Goethe in one of his novels (*Die Wahlverwandschaften*, I believe), describes a lady as seized with a sudden chill upon a spot where subsequently the outcrop of a coal-bed is discovered. The incident is introduced without attempt at scientific explanation, and apparently to convey to the reader a vivid conception of the lady's extreme delicacy of temperament. I infer from it that such cases were known to the great philosopher, and that he believed such supersensitiveness to be in some way connected with the performances of diviners.

To this then, the rod of Moses, of Jacob, of Mercury, of Circe, of Valentine, of Beausoleil, of Vallemont, of Aymar, of Bleton, of Pennet, of Campitti—even of Mr. Latimer—has come at last. In itself it is nothing. Its claims to virtues derived from Deity, from Satan, from affinities and sympathies, from corpuscular effluvia from electrical currents, from passive perturbatory qualities of organo-electric force, are hopelessly collapsed and discarded. A whole library of learned rubbish about it, which remains to us, furnishes jargon for charlatans, marvelous tales for fools, and amusement for antiquarians, otherwise it is only fit to constitute part of Mr. Caxton's *History of Human Error*. And the sphere of the divining-rod has shrunk with its authority. In one department after another, it has been found useless. Even in the one application left to it with any show of reason, it is nothing unless held in skillful hands, and whoever has the skill may dispense with the rod. It belongs with "the magic pendulum" and "Planchette," among the toys of children. Or if it be worthy the attention of scientific students, it is the students of psychology and biology, not of geology and hydroscopy and the science of ore deposits, who can profitably consider it. For us miners and prospectors, the advise holds good which was given us three hundred years ago by the wise Agricola, the father of our profession, who says the believers in the rod find

some veins with it by accident. "*Sed idem multo saepius perdunt operam, et ut venas invenire possint, nihilominus in fossis agendis defatigantur, quam adversae partis metallici.*"—"but the same people much more frequently lose their pains, and in order to discover veins have to fatigue themselves with digging, not less than the miners of the opposite school."

As a piece of sorcery, he goes on to say, the virtuous and respectable miner will avoid it; as a piece of science, it is inferior to the study of nature, following the indications of which, the skillful and prudent miner selects a good place for exploration, and "*ibi metallicus agit fossas*"—"there the miner digs"—to which business, rod or no rod, he is bound to come at last.

SPONTANEOUS DECOMPOSITION OF EXPLOSIVE GELATINE.—According to Abel, neither trinitrocellulose nor the less nitrated products are affected, when pure, by a temperature near 100°, but the easy decomposibility of gun cotton, sometimes observed, is due to the presence of nitro-derivatives of foreign organic substances (the incrusting matter of the cellular tissue), which, when heated, quickly decompose with formation of free acid. Prof. Chas. E. Munroe, U. S. N. A., reports the following case which has occurred under his own observation. Some camphorated explosive gelatine was wrapped in paraffine paper, then in light brown Manilla paper, and laid on a shelf. After something more than a years' exposure it was found, in the early winter, to be giving off nitrous fumes and to have shrunk considerably in volume, while the outside of the paper was covered with congeries of fine crystals. The odor of camphor was still quite strong. The mass was immediately put into a vessel of water. It was found to be friable, and, after a short immersion, disintegrated. The camphor odor soon disappeared, and the water became of a straw color, gave a strong acid reaction, and showed traces of nitrous acid, but no nitric acid. On evaporation of the filtered liquid, oxalic acid crystallized out in quantity, and on evaporation of the "mother liquor" on the water-bath, a sugar-like mass was obtained, which gave the glucose reaction with Fehling's solution. The paraffine was regained unchanged, and the paper was recovered, but in a flocculent condition, and with the color bleached from the brown. Careful search failed to reveal the presence of glycerine, nitro-glycerine, or gun-cotton.—*Jour. Amer. Chem. Soc.*, vol. 6, Feb. 1884. C.

A NEW REFRACTORY BRICK.—A French engineer has introduced a refractory brick of pure graphite, by perfectly agglomerating the powder of that substance. It is well known that graphite is nearly infusible at the highest temperatures that can be produced and this new class of bricks will doubtless prove very serviceable in metallurgy, where the want of linings which are wholly infusible has long been felt.—*Gaceta Industrial*, March 25, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 5.—Edison's Telephonic Inventions.

It is a significant fact that, of the four men, Bell, Gray, Dolbear and Edison, who have had so much to do with the present condition of the articulating telephone, and whose labors have enabled it, to so great an extent, to occupy its present commercial position, three of them, Bell, Gray and Edison, were for several years previous to its extensive introduction, engaged in active work on different systems of multiplex-harmonic telegraphy.

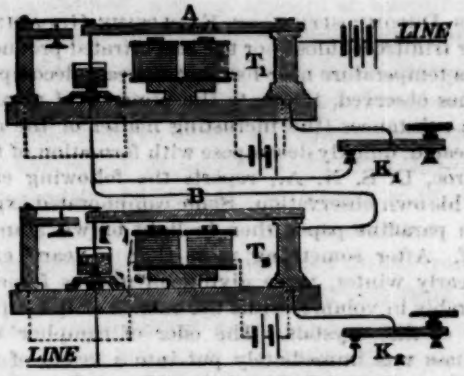

Fig. 1.—Edison's Acoustic Telegraph.

The different systems of multiple telegraphy thus developed, though differing in their details, are all dependent for their operation on the transmission, over the main line, of electrical impulses that are varied at the regularly recurring periods necessary for the reproduction of the pitch of the musical sounds transmitted. The electrical currents sent into the line are simultaneously varied in their intensity by the vibrations of reeds tuned to produce several notes of different pitch. On reaching the distant end of the line the currents, thus superposed on one another, are caused to impart a vibratory motion to tuned electro-magnetic receivers, whose rates of vibration correspond to the rates of vibration of the transmitting instruments. The receiving operator at the distant end of the line, having his instrument sensitive to the signal sent by his correspondent at the transmitting

end, is thus unaffected by the signals that are being simultaneously transmitted by the other instruments.

With a knowledge of the results already achieved by Reis in articulate telephony, the mere fact of constantly dealing with such varied electrical currents was naturally enough followed by marked improvements in the articulating telephone.

Edison began his investigations in multiplex-harmonic telegraphy in September, 1875, when he constructed an arrangement whereby two tuning-forks of different rates of vibration, were kept in constant motion by the action of an electro-magnet. A battery electrode, attached as a metallic point to one of the tines of each of the forks, dipped into a vessel containing acidulated water, and during the vibration of the fork, was moved towards and from the other electrode. Under the variations in the resistance thus effected, undulatory currents were sent over the main line. This form of apparatus is shown in Fig. 1.*

In this form of apparatus a local battery is provided for the vibration of the fork and its movable electrode. The movements of this electrode in the liquid, towards and from the metallic point in the bottom of the vessel, vary the otherwise constant electric current in the main battery connected with the line, and thus send an undulatory current over the line. Keys K_1, and K_2, are used for signalling, by the short circuiting they effect. The receiving apparatus for this device is shown in Fig. 2.

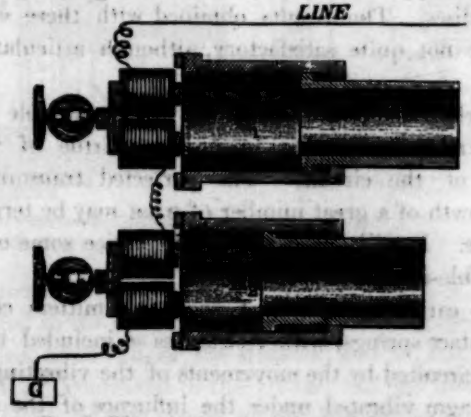

FIG. 2—Edison's Acoustic Telegraph Receiver.

* The author is indebted for Figs. 1, 2, 9 and 10, to *The Speaking Telephone and Talking Phonograph*, by George B. Prescott.

It consists essentially of the two electro-magnets connected to the main line. Opposite the poles of these magnets are placed two hollow vessels, R_1, and R_2, to the ends of which are soldered iron diaphragms. Although the undulatory currents produced by both transmitting forks, pass through the electro-magnets of each of the receivers, R_1, and R_2, and therefore affect their diaphragms, yet the resonant column of air in each of the receivers, being tuned by means of a sliding or telescopic joint, to vibrate in unison with but one of the sounds, that sound only is heard, to the exclusion of the other. When, therefore, the transmitting keys are operated, the signals, resulting on the starting or the stopping of the vibrations, are heard in their appropriate receivers only, that sent by T_1, being repeated by R_1, only, and that sent by T_2, by R_2, only.

Mr. Edison's early inventions in telephony were mainly in the direction of transmitting instruments of the type that depend for their operation on variations produced by the voice in the electrical resistance of a battery circuit. Any form of electro-magnetic receiving telephone is suitable for use with such transmitters. His first experiments were made with Reis transmitters, to which he applied the method of gradually varying the strength of the current by the introduction of a drop of water between the platinum point and the diaphragm. The receiver used with this transmitter was that shown in Fig. 2. He also modified this form of apparatus by placing several drops of water between two metallic discs. The results obtained with these early forms of apparatus were not quite satisfactory, although articulate speech was obtained.

Edison's carbon telephone forms his most valuable contribution to telephone transmitters, that operate in virtue of variations in the resistance of the circuit. The perfected transmitter was the gradual outgrowth of a great number of what may be termed preparatory inventions. It will be of interest to notice some of these early forms of variable-resistance transmitters.

One of the earliest patented of such transmitters consisted in a number of contact springs, with resistances so included between them as to be short circuited by the movements of the vibrating diaphragm. As the diaphragm vibrated under the influence of the sound waves these resistances were alternately cut out, or introduced into the circuit of a battery. This form of transmitter is shown in section in Fig. 3.

The diaphragm, g, has interposed between it and a flexible conduc-

tor, *D*, an elastic cushion, *f*, formed of a piece of rubber tube, fastened to the diaphragm. The object of this arrangement is to prevent the setting up of false vibrations.

A number of metallic springs, e^1, e^2, etc., form the terminals of a series of resistance coils. These springs are placed contiguous to the flexible metallic strip *D*, so that when *D*, is moved to and fro by the vibrations of the diaphragm it comes into contact with e^1, just a moment before it does with e^2, and so on. When *D*, touches both e^1, and e^2, the resistance coil included between them is cut out, thus lessening the resistance of the battery circuit. On a more vigorous movement of the diaphragm, the flexible strip *D*, touching all the contact points, thus cuts all the resistance out of the battery circuit. The strength of the electric waves sent into the line is therefore proportional to the amplitude of the vibration of the diaphragm, or to the loudness of the sound waves.

In Fig. 4, is seen a rear view of the diaphragm, showing the arrangement of the rheostat wires and the mode of winding the same.

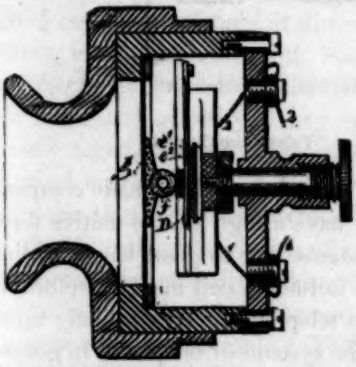

FIG. 3.—Edison's Rheostat Transmitter (Section).

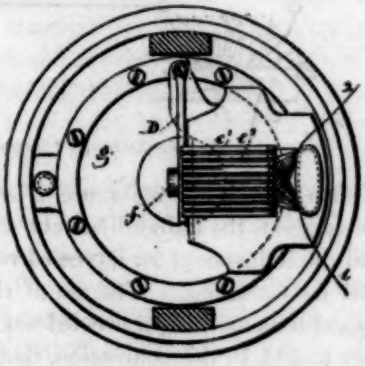

FIG. 4.—Edison's Rheostat Transmitter (Rear View).

Fig. 5, shows the circuit connections; h^1, h^2, h^3, h^4, h^5, etc., are resistances connected to the contact springs e^1, e^2, e^3, e^4, e^5, etc. An induction coil, *A*, formed, as shown, of the coils m^1, and m^2, has the ends of its secondary coil m^2, connected to the ground and the line. The primary wire m^1, is placed in the circuit of the battery, *c*, and the resistances h^1, h^2, h^3, h^4, h^5, etc. *B*, is the receiving instrument, and B^1, its diaphragm armature.

The use of the induction coil, with any form of variable resistance

transmitter, marks a great advance in telephony. The maximum variation produced by the voice in the resistance of any transmitter must, necessarily, form a comparatively small portion of the total resistance of the main line with all its instruments. When, therefore, the direct battery circuit is employed on the main line, the variation produced in the strength of the current by the transmitter must necessarily be weak, and the sounds produced by the receiving instrument, at the distant end of the line, correspondingly weak. But when the battery is short circuited, through the variable resistance and the primary of the induction coil, the variations in the resistance produced by the voice are comparatively great, and corresponding variations are sent over the line by means of the induced currents set up in the secondary coil.

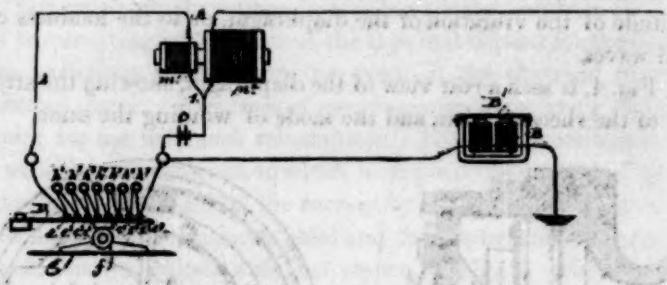

FIG. 5.—Edison's "Secondary" Telephone Circuit.

Then, too, if the resistance of the secondary coil be made comparatively great, the induced current will have a high electro-motive force, and the influence of an increased resistance, due to great length of line, will be much less.. The use of the induction coil may, therefore, be regarded as marking a decided era in telephony. It is scarcely necessary to add, in this connection, that the systems of telephony in general use are greatly dependent for their successful operation on the employment of induction coils.

The uninsulated rheostat-transmitters shown in Figs. 3, and 4, were modified by Edison in a variety of ways. For example the rheostat was given the form of a long, thin, platinum wire, wrapped in a spiral form, around the outside of a cylinder of some insulating material, and so placed that the forward movement of the diaphragm causes the metallic spring to successively short-circuit each convolution of the wire rheostat, thus decreasing the resistance of the circuit.

In another form of rheostat-transmitter, a coil of uninsulated wire

is loosely wrapped around a vertical, insulating support, so that the movements of the diaphragm produce a compression or elongation of the spring, and thus throw its successive convolutions into or out of the circuit.

Although articulate speech was obtained by the use of the rheostat-transmitters described above, yet the effects were by no means of a satisfactory character. The variations in the resistance were of too sudden a character. Instead of the resistance being gradually varied by the movements of the transmitting diaphragm, they were thrown in abruptly. The diaphragm would move so as to cut out one of the resistances thus throwing a sudden variation on the circuit. Then no further variation would occur until the diaphragm had reached the next contact point when another sudden variation would occur. It therefore followed that the speech, reproduced by the receiver, was confused and often unintelligible, and quite deficient in either its finer modulations of intensity, or in its quality.

These difficulties were obviated by the invention of what Edison terms his "articulators, or electric tension regulators." These consisted essentially of tufts of fibrous materials, such as asbestos, sponge, cotton, wool, feathers, or silk, coated or covered with a thin layer of any electrical conducting material such as plumbago, metallic powders, etc. A small quantity of any of these materials so prepared, placed loosely together between two rigid plates so as to be compressed by the forward movements of the diaphragm, will gradually, but markedly, vary the electrical resistance of a circuit in which it is placed.

The following description of one of these "articulators" will serve to render the preceding clearer. The fibrous material is preferably elastic, so as to avoid permanent compression during use. For this purpose silk is preferable. The unspun fibre is cut in lengths of say the one-sixteenth of an inch, and coated with plumbago, either by rubbing or otherwise. The fibres are then rolled together with a little loose plumbago in a cigar shape and retained in shape by a few binding fibres of silk.

The fibre rheostat so obtained is then placed at *f*, Fig. 6, between the adjusting post *d*, and the diaphragm *b*. The adjusting post *d*, is provided with a metallic plate *c*, connected to one of the terminals of the circuit. The diaphragm *d*, is made of mica, and is provided with a conducting plate, or spring *e*, which through the conducting spring *a*, connects it with the other pole of the battery. The "articulator" *f*,

therefore, is inserted as a variable resistance in the circuit. Any movement of the diaphragm will result in producing considerable variations in the resistance in the circuit due to the variations in the pressure on the bundles of conducting fibre.

Since these variations are due to the number of conducting points on the surface of the fibre that are brought into contact by the increased pressure of the diaphragm, the variations in the resistance must necessarily be of a gradual character, in contradistinction to the abrupt variations effected by the first form of transmitter.

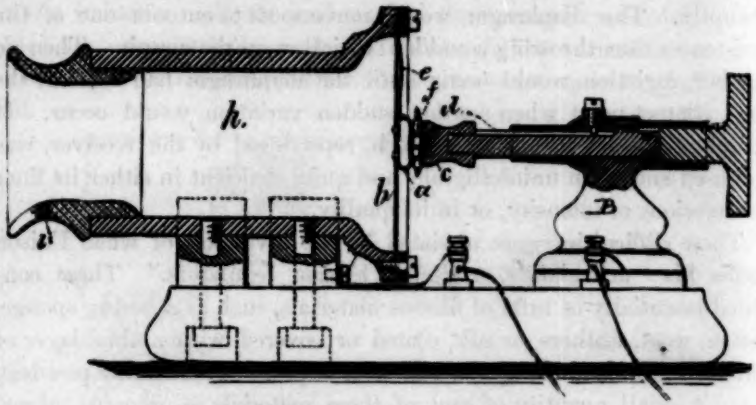

FIG. 6.—Edison's "Fibre Articulator."

The mica diaphragm, first employed for telephones by Edison, possesses, it is claimed, many advantages over the ordinary metallic diaphragm. Its advantages over any of the old forms of membranous diaphragms employed by Reis are evident, since the mica is not as much effected by the moisture of the breath, or by changes of temperature. Its advantages over the metallic diaphragms, are not, however, so apparent, since, being composed of a number of more or less parallel plates of varying thickness and elasticity, it is difficult to see how such a plate could as freely accept the rapidly varying rates of the vibrations of the sound waves, as could a homogeneous, highly elastic, metallic plate of uniform thickness.

The aperture at *i*, in the mouth-piece, is provided so as to avoid the hissing sounds produced by many of the consonants.

From transmitters in which the resistances consisted of elastic non-conducting materials, more or less covered with conducting substances, the step to resistances consisting entirely of conducting substances was

but natural. This step led to the invention of Mr. Edison's carbon transmitter, which must be regarded as an extremely valuable contribution to telephony.

Edison tried numerous experiments with variable resistances consisting throughout of solid conducting materials, before he fully demonstrated the valuable properties possessed by carbon in its various conducting forms. One of his earlier forms of carbon telephone is shown in Fig. 7.

FIG. 7.—Edison's Carbon Transmitting Telephone (Earlier Form).

The cap 10, serves to hold the diaphragm firmly at its edges. A piece of cork or rubber tube is secured to the middle of the diaphragm. This tube is adjusted so as to rest against an ivory disc, provided on its outer face with a platinum disc. An adjustable rod, 5, is also provided at its upper end with a platinum disc. Between these two platinum discs is placed the carbon rheostat, which in this case is composed of a button of lamp-black carbon, 6. The two platinum discs serve as conductors by means of which the carbon rheostat, and the primary wire of an induction coil are included in the circuit of a battery. An adjusting screw, 3, is provided for regulating the pressure on the carbon rheostat.

By numerous experiments Edison found that carbon of high electrical resistance is not as well adapted for a rheostat as is carbon of a higher conducting power, since with very high-resistance-carbon the movements of the diaphragm by the action of the sound waves would not produce the requisite change of resistance. He at first sought to increase the conducting power of the carbon by mixing other substances with it so as to separate its particles, but found that treated in this way its resistance became too great to permit its use in connection with the primary circuit of an induction coil.

Fortunately, however, he discovered that the variety of carbon produced by the imperfect combustion of such light hydrocarbons, as gasoline

or naptha, was capable of undergoing considerable changes in its conducting power when submitted to variations of pressure.

The carbon button is prepared as follows, viz.: The darkest portions of the carbon obtained from the soot of burning naptha as before mentioned, is selected, and the mass then subjected to a powerful pressure so as to effect a consolidation. This button is placed in the telephone in the manner shown in connection with Fig 7.

The success attained by Mr. Edison's telephone resulted from the fact that the variations in the resistance of the carbon button under variations of pressure, being dependent entirely on the pressure, varied directly with it. The use of the cork, or rubber disc 8, is intended to prevent the continuance of the vibration of the plate under the action of the voice, after the tone of the voice causing a particular vibration has ceased to act. In this way the distinctness of articulation is very greatly improved.

The use of this rubber tube, however, gave rise to the necessity for continual readjustment due to its gradual change of shape. To avoid this difficulty Edison replaced this rubber tube by a short spiral metallic spring formed of a few turns of stout wire. This modification is shown in section, in Fig. 8.

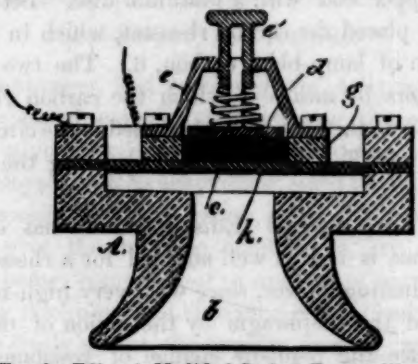

FIG. 8.—Edison's Modified Carbon-Transmitter.

The mouth-piece *b*, is furnished with a stout diaphragm *k*, firmly secured at its edges in the manner shown. The centre of this diaphragm, on which the carbon button, *c*, rests, is platinized in order to ensure a good contact. The button formed of prepared carbon, is placed on the centre of the diaphragm inside a metallic ring *g*, and is surmounted by a metallic plate *d*, held in position against the button by the spring

e, formed of a few turns of stout wire. The pressure exerted by the spring *e*, against the metallic plate *d*, is regulated by means of the screw *e*. The carbon button *c*, is placed in the circuit of a battery by means of the conducting wires placed on the left side of the figure.

Since the ring *g*, and the circuit regulating devices are supported on the middle of the diaphragm, it is evident that when the diaphragm is set into vibration by the sound waves, the variations in the resistance of the carbon button are influenced by the inertia of the ring and the circuit regulating devices.

This form of instrument was found in practice to possess a disadvantage, owing to the fact that the tendency of the spring to a definite rate of vibration caused it to produce a musical note that interfered with the distinctness of the articulation. It was in his attempt to remedy this defect that Edison was led to the discovery of a principle of great importance to the successful use of the carbon telephone.

Attempting to avoid the musical note emitted by the spring, he made it of thicker and thicker wire, when he found the clearness of the articulation to become greater and greater. This showed that the increase in the inelasticity of the spring had no effect on the articulation. He inferred, therefore, that since the springs were unnecessary, the action of a transmitter did not require the sound waves to produce an actual vibration of the diaphragms. When the sound waves struck the diaphragm they produced a direct variation of pressure thereon, and thus varied the resistance. He used diaphragms, therefore, that were so thick that the loudest sounds produced no sensible vibrations therein, and fastened the carbon disc and plate tightly together. By these means very excellent results were obtained.

The effects produced by variations of pressure on the conductivity of carbon are well shown by means of the apparatus seen in connection with Fig. 9. The circuit of the battery cell *B*, has inserted in it a

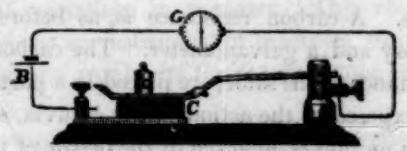

FIG. 9.—Experimental Apparatus.

galvanometer *G*, and a carbon button *C*. The circuit being closed, the needle of the galvanometer showed a certain deflection. If, now,

the weight G, be placed on the carbon in the position shown, the needle of the galvanometer is at once deflected by a more powerful current, thus showing that the resistance of the circuit has been decreased by the increase of pressure. A further addition of weights results in a a greater decrease in the resistance of the circuit.

Edison was aware of and had practically applied the principle of the variable resistance of carbon with variation of pressure, long before he applied it to the construction of his carbon telephone transmitter. For example, as early as 1873, he invented his form of carbon rheostat. This instrument was devised in order to supply an artificial resistance in cable experiments. It consisted essentially of finely divided carbon contained in a glass tube. The carbon varied in resistance with the pressure to which it was subjected. The carbon rheostat does not appear to have been very successful, owing, doubtless, to the fact that its resistance varied greatly with the expansions and contractions of the enclosing glass tubes. It was also varied in resistance by sudden jars or even noises.

Edison has applied the principle of the variation of carbon under pressure to a variety of other uses. Some of these applications were made prior to the invention of the telephone. His micro-tasimeter for measuring radiant heat is one of the most ingenious of these applications. A carbon resistance is included in the circuit of a battery and a galvanometer. The expansion of a metallic rod or bar, by the action of the heat, varies the resistance of the circuit and thereby affects the needle of a delicate galvanometer. This instrument is exceedingly sensitive to very slight variations in temperature and has been employed in some refined investigations. Unless very carefully managed, however, its indications are unreliable, owing to the accidental variations in the resistance of the carbon.

What Edison terms his odorscope is a somewhat similar apparatus. It is designed, we are informed, to electrically detect the presence of various odors. A carbon resistance is, as before, included in the circuit of a battery and a galvanometer. The carbon, and means for varying the resistance of the same, are placed in a partially closed vessel where they are exposed to the action of the effluvia, or odor, that is to be detected, and a motion is observed in the needle of the galvanometer. This motion, it need scarcely be added, is not, in all probability, to be attributed to any molecular action due to the effluvia or odorous particles on the carbon resistance, or on the metals or other substances that

are connected therewith, but rather to pressures resulting either from variations in the temperature, or from contraction or expansion consequent on the changes in the hygrometric condition of the absorbent materials.

Another application more directly in the line of telephone inventions is a telephonic repeater. This form of apparatus is shown in connection with Fig. 10.

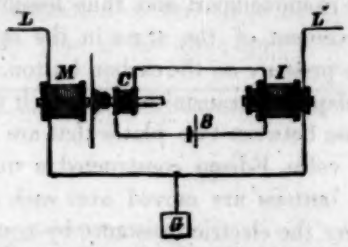

FIG. 10.—Edison's Telephone Repeater.

The local battery *B*, has included in its circuit the primary wire of an induction coil *I*, and a carbon resistance *C*, which acts as the transmitter. This resistance is so connected with the plate of iron opposite the electro-magnet *M*, that it responds to any variations in the strength of the current flowing through the coils of *M*, connected with the main line. When, therefore, a current, which has been varied by the voice of a speaker at a distant transmitter, traverses the coils of *M*, it produces variations in the resistance of *C*, that cause an exactly similarly varied current to flow over the line connected with the secondary coil of the induction coil *I*.

Another application of the same principle is seen in Edison's pressure relay for telegraphic use, invented in 1873, in which the variations in the conducting power of carbon, under variations of pressure, are used to automatically transfer signals from one circuit to another.

Edison has also employed this property of carbon to construct a rheostat, or carbon resistance, that is capable of being greatly varied in resistance with variations in pressure. This rheostat is not, however, very reliable as an instrument of precision, owing to the fact that the carbon does not regain its former resistance on the relief of the pressure.

In the employment of carbon as the variable resistance in telephone transmitters, Edison has obtained the variations of pressure by the action of the sound-waves in a variety of ways. Besides those we have already pointed out, he has contrived a transmitter in which the motion

of the diaphragm, under the action of the sound-waves, effects an increase in the resistance of the circuit when the diaphragm moves inwards, and a decrease when it moves outwards under the influence of its elasticity. This he effects by supporting the carbon button between metallic cups connected with uprights secured to the middle of the diaphragm. The inward motion of the diaphragm, on the impact of the sound-waves, causes the uprights to move apart and thus lessen the pressure on the carbons. The movement of the arms in the opposite direction of course increases the pressure on the carbon button.

In addition to telephonic transmitters in which the carbon resistance is placed in one mass between two plates that are urged to and fro by the action of the voice, Edison constructed a number of devices in which two carbon buttons are moved over each other by the sound-waves, and thus vary the electric resistance by reason of the greater or less intimacy of the contact, or by reason of the number of points thus brought into contact. This form of telephonic transmitter was termed by him the "micro-telephone," on account of its ability of responding to much feebler sounds than the other transmitting instruments. This form of transmitter was, in fact, a form of "microphone transmitter." The U. S. Patent descriptive of this modification of transmitter was filed on the 11th of November, 1878.

Edison's micro-telephone is shown in section, in Fig. 11.

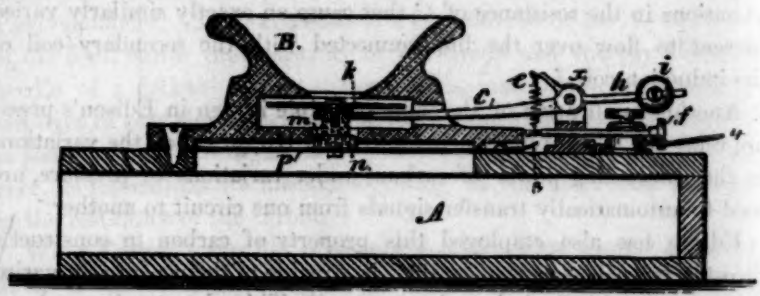

FIG. 11.—Edison's Micro-telephone.

The apparatus is mounted in a hollow, resonant box, *A*, and consists of a mouth-piece, *B*, furnished with two diaphragms *p*, and *k*.

The diaphragm *p*, is placed over a circular opening, in the resonant box *A*; upon this diaphragm is placed a piece of compressed carbon *n*, and a second piece of carbon *m*, secured to a lever *c*, pivoted at *x*, is placed on the carbon *n*. The arm *h*, of this lever, is provided with a movable

weight *i*, intended to counterpoise the weight of *c*, and its connected parts. The spring *e*, serves to vary the pressure of the carbon buttons, *m*, and *n*, on each other. The diaphragm *p*, is securely attached at its edges to the resonant box. The diaphragm *k*, which consists of some light material, like mica, is free at its edges, and is connected by means of a screw to the end of the lever *c*, and placed below the mouth-piece *B*, in the position shown. The arrangement of the circuit is better shown in the plan of the same apparatus in Fig. 12.

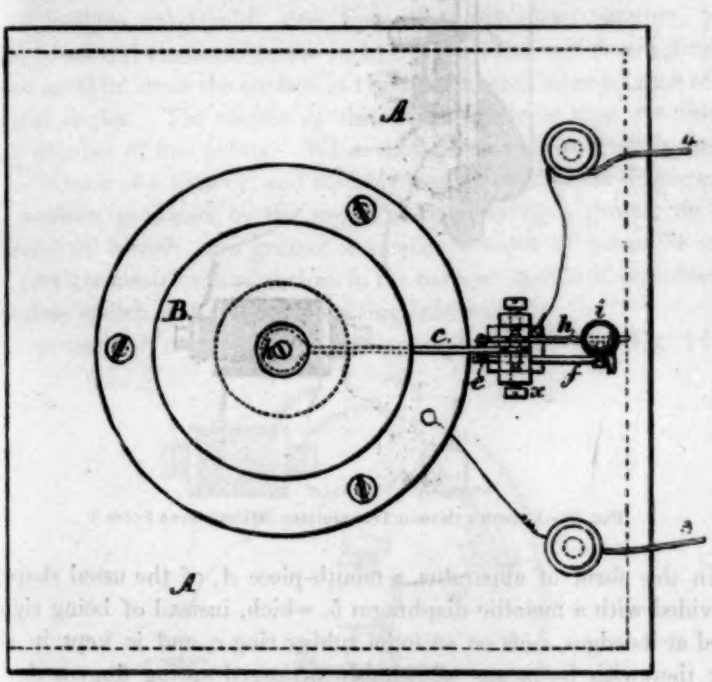

FIG. 12.—Edison's Micro-telephone (Plan.)

The terminals 3, and 4, of a battery are connected respectively to the lower and upper carbon, by being attached to the edges of the metallic diaphragm *p*, and to the arm of the lever *c*.

Exceedingly slight jars or vibrations given to this apparatus, such as by a person walking across the room in which it is placed, or by the sound waves produced by the voice of a distant speaker, vary the current sufficiently to reproduce the voice of a speaker in a suitable receiving instrument.

A modified form of microphone transmitter invented after the preceding is shown in Fig. 13.

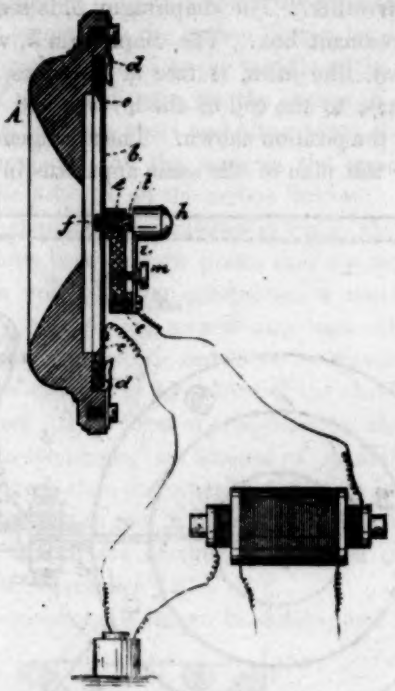

FIG. 13.—Edison's Carbon Transmitter (Microphone Form.)

In this form of apparatus, a mouth-piece *A*, of the usual shape, is provided with a metallic diaphragm *b*, which, instead of being rigidly fixed at its edges, rests on an india rubber ring *c*, and is kept in contact therewith by means of suitably arranged spring fingers *d*. In order to avoid a grating sound by the rubbing of the diaphragm against the metallic spring fingers, the latter are covered with rubber.

There is attached to the centre of the diaphragm by means of a metallic screw *f*, a block *e*, *e*, of insulating material. This block is recessed opposite the screw attachment, for the reception of a button *l*, of hard carbon, or plumbago. A weight *h*, supported on a spring-arm *i*, has one of its surfaces in contact with the carbon button as shown. This surface is platinized in order to ensure a good contact.

The circuit connections are apparent from an inspection of the drawing. The circuit of the battery cell is completed by means of the con-

ducting wires through the carbon button *l*, and the primary of an induction coil.

The operation of this form of transmitter is evidently dependent on the difference in the pressure against the carbon, which is produced from the inertia of the weight *h*, acting as a resistance to the free movement of the diaphragm.

Edison devised a curious form of transmitting instrument, which he patented in 1882. This transmitter consists substantially of a surface or of surfaces ruled with fine lines that are close together, preferrably several thousand to the inch. These lines, which are parallel to one another, cross the surface in two systems that intersect each other at right angles. The surface of the striated plate is thus cut into a great number of fine points. When surfaces so prepared, are included in the circuit of a battery, and suitably combined with the diaphragm, the motions produced by the sound waves, causing a greater or less intimacy of contact, or a greater or smaller number of points in contact, produce electrical undulations in the current capable of reproducing articulate speech in a suitable receiving instrument.

A transmitter, constructed on this principle, is shown in Fig. 14.

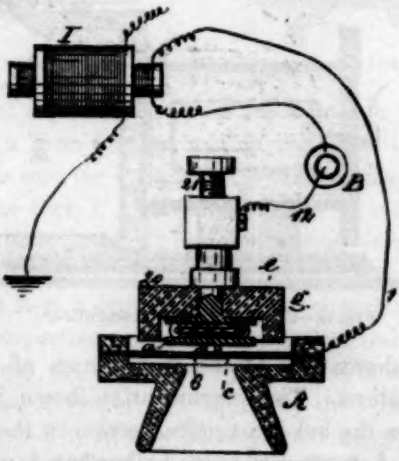

FIG. 14.—Edison's Striated-surface Transmitter.

The mouth-piece *A*, is provided with a metallic diaphragm of the usual construction. The striated surface, which in this case consists of a strip of platinum, scored by fine lines as above described, is folded in a flat form with a piece of felt or rubber within the fold, and the

scored surfaces placed in contact with the plates *a*, and *e*. The plate *a*, rests on a short section of rubber tube 6, supported at the centre of the diaphragm. The plate *e*, is connected with the adjusting screw 21, provided for the purpose of regulating the pressure between the surfaces in contact.

The scored platinum foil is therefore placed in the circuit of the battery *B*, and the primary wire of the induction coil *I*, by means of the conducting wires 12, and 1, as shown. It replaces the carbon button of his earlier carbon transmitter, and operates to produce a change in the conducting form of the battery circuit in a somewhat analogous manner.

Since Edison employed a movable electrode in water for varying the current in a line, as early as 1873, in connection with his system of acoustic transmission, it is quite natural to find that he was one of the first to apply the principle to the operation of a transmitting instrument for a telephone, as soon as the telephone became generally known. He devised quite a number of liquid transmitters.

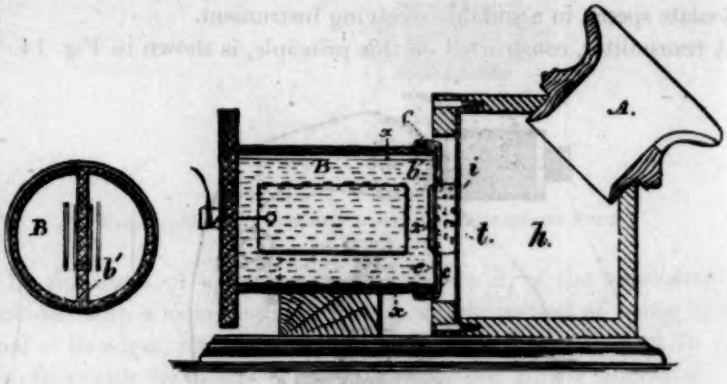

FIG. 15.—Edison's Liquid Transmitter.

In Fig. 15, is shown one of the many forms of liquid transmitters devised by Edison. The instrument is shown in vertical longitudinal section; on the left is a vertical section on the line *x x*.

A mouth-piece *A*, is attached to the hollow box *h*, which is provided with a rigidly attached diaphragm *i*, of mica, as shown. *B*, is a cylinder of non-conducting material, divided by b^1, as shown in the vertical section on the left, into two compartments by a non-conducting material. The cylinder *B*, is provided with two electrodes of platinum, carbon or

other conducting substances, connected respectively to line and earth. These electrodes project towards the diaphragm *i*, somewhat beyond the vertical non-conducting partition. The diaphragm *i*, has rigidly attached to its face, a piece of cork *t*, which projects inwards through a slot in the end of the cylinder *B*, and when in position leaves a small space at 2, which limits the passage of currents between the electrodes.

When the sound waves fall on the mica diaphragm *i*, the passage 2, is alternately decreased and increased as the cork *t*, is moved towards or from the electrode, and the resistance of the battery being thus varied, electrical undulations are thrown on the line.

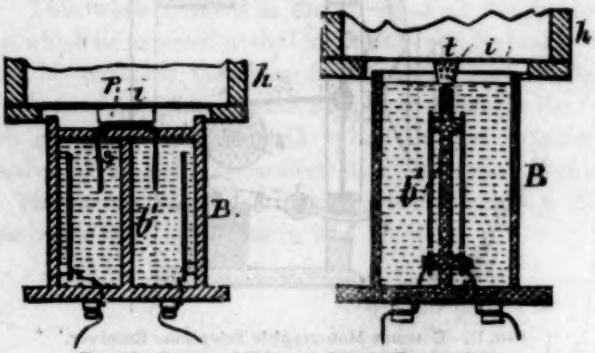

FIG. 16.—Forms of Edison's Liquid Transmitter.

Other forms of liquid transmitters are shown in Fig. 16. On the right is shown a form similar to that described in connection with Fig. 15. In this case the cylinder *B*, is vertical, the conducting liquid space between the cork *t*, and the electrodes is more clearly shown. The division of the cylinder *B*, into two separate compartments by the non-conducting partition b^1, is also more clearly shown.

On the left is seen a device in which the partition b^1, completely closes the two compartments. In this case electrical communication is established between the electrodes by means of a conducting wire *s*, that is moved into or out of the liquid by the vibrations of the diaphragm. The liquid in *B*, may be acidulated water, or mercury.

One of Mr. Edison's most valuable contributions to telephony is to be found in his loud-speaking telephone. This instrument is based on the principle of his motograph, which he patented in the United States on January 19, 1875. By the application of this principle to the telegraph, he was enabled to produce motions in distant telegraphic

apparatus, independently of electro-magnetism, or of the motion of galvanometer needles.

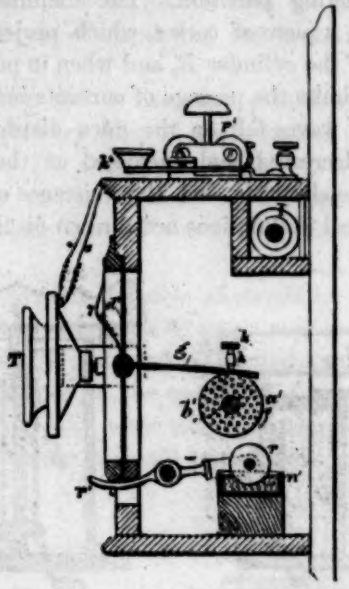

FIG. 17.—Edison's Motographic Telephone Receiver.

The principles of the motograph are well explained by Edison in United States Patent, 158,787, as follows: "The principles of its operation are that, when a moving surface is in contact with a slightly-yielding substance, the tendency is to move the latter by and with the former. If the circumstances of contact are varied, the adhesion of the surface will be sufficient to cause the moving surface to move the yielding substance, or else to cause the yielding substance to slip more freely, and by its spring go in the opposite direction to the moving surface. I have discovered that the passage of electricity through the surfaces in contact will change the frictional adhesion, making it more or less, according to the substances employed; and by balancing the chemical forces so that when the surfaces in contact are not electrified the moving surface carries with it the yielding surface, and when electrified the yielding surface slips back over the moving surface, and *vice versa*, a mechanical movement is produced that is dependent on the electrical condition of the surfaces in contact; hence mechanical motion is obtained, first one way and then the other, that is as unlimited

in its speed as the pulsations of electricity that pass, unobstructed by magnets, or other hindrances, over the telegraphic line."

Edison describes in this patent a telegraphic instrument capable of being operated by means of the Morse system, in which the variations in friction obtained as above described are utilized.

Fully aware of the ability of an electrical current to vary the friction between two surfaces, and thus reproduce mechanical motions at the distant end of a telegraph line, it is quite natural that he should at an early date in his telephonic investigations, turn his attention to the motograph principle in connection with systems of telephonic communication. This work resulted in the invention of his loud-speaking telephone, which he patented in the United States on November 25, 1879.

Edison's Motographic Telephone is shown in section in Fig. 17.

In this form of apparatus he utilizes the variations in the friction of a metallic rod on a rotating chalk cylinder. The cylinder a^1, is of compressed chalk, soaked in some electrolyzable solution, such as caustic potash. The shaft b^1, is rotated by means of the handle f, shown in a back view of the same apparatus in Fig. 18.

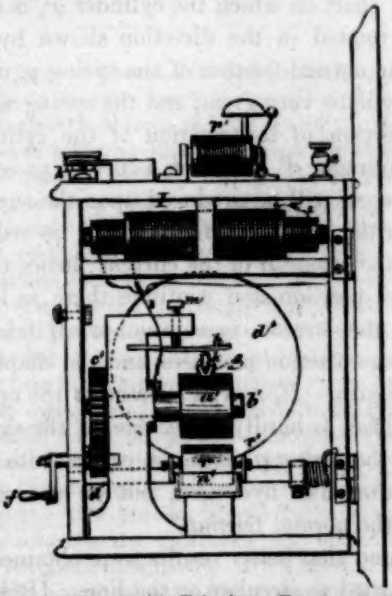

FIG. 18—Edison's Motographic Telephone Receiver. (Back View).

Of course, the chalk cylinder may be rotated by clockwork, or by any other suitable means.

A flat, metallic spring g, attached at one end to the centre of the diaphragm d^2, rests on the surface of the chalk cylinder. The pressure of this spring against the cylinder is regulated by means of the screw h. In Fig. 19, a plan of this receiver is shown.

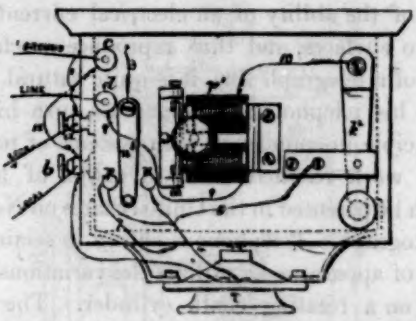

FIG. 19.—Motographic-Receiver. (Plan).

"The line-wire is connected to the spring g, while the earth-wire is connected to the shaft on which the cylinder a^1, is secured. If, now, the cylinder be rotated in the direction shown by the arrow and no current passes, the normal friction of the spring g, upon the surface of the cylinder a^1, will be very great, and the spring will be carried forward in the direction of the rotation of the cylinder, thus pulling inwardly the diaphragm d^2. If, now, a current passes, whose direction is such that hydrogen will be produced upon the surface of the spring g, in contact with the chalk, the friction will be reduced to an extent proportionate to the strength of the current; hence the diaphragm will regain its natural position and continue there as long as the current passes. If, now, the current ceases, the normal friction at once is re-established, and the friction increases, and the diaphragm is violently pulled inwardly again. If, now, a current in the opposite direction is transmitted, the effect is hardly noticeable, as the evolution of oxygen on the surface of the spring g, does not, except with a few saturations, decrease the friction like hydrogen, but on the contrary, generally tends to increase the normal friction."

Mr. Edison found that better results were obtained when a constant current was permitted to circulate on the line. He has also found that quite a number of different electrolytes may be employed to saturate the chalk cylinder. The acetate of mercury, mixed with caustic soda,

is one of the best. In order to readily moisten the surface of the chalk cylinder the vessel u^1, is provided freely with water. The lever r^1, moves a felt wheel r, against the chalk when the latter has become too dry.

The sound-waves impinging against the transmitter T, which contains the ordinary carbon button, varies the current of a battery, that passes through the primary of an induction coil I, and thus produces positive and negative waves in its secondary coil, which passing over the line cause variations in the adhesion of a metallic strip to a rotating chalk cylinder, similar to that shown at a^1, and g, and therefore cause motions, in its diaphragm that reproduce the speaker's voice.

Since the resistance of the spring and the chalk are greater when the chalk is at rest, than when in motion, the chalk cylinder and its opposing spring may, if so desired, be employed as a transmitter in the place of the carbon transmitter.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, December 15, 1884.

GLOBULAR LIGHTNING.—Gaston Planté described, some years ago, under the name of "Walking electric spark," a peculiar phenomenon produced by the passage of an electric current of high tension. The appearances are so analogous to those of globular lightning, that he considers that phenomenon as a slow and partial discharge of the electricity from storm clouds, when that electricity is exceptionally abundant, and when the cloud itself, or the column of strongly electrified damp air, which forms its electrode, so to speak, almost reaches the ground, or is only separated from it by a thin layer of insulating air. Under these circumstances the ponderable matter which is traversed by the electric current collects under the form of a globe of fire. It is a kind of electric egg, without a glass envelope, which is formed by the rarefied and incandescent elements of air and vapor. The globe is not fulminating and dangerous by itself, for a breath is often sufficient to displace it or even cause it momentarily to disappear. Its presence however is formidable, for it brings the electricity from the storm cloud and reveals the chosen path of its escape. If the layer of air which separates the cloud from the ground is not traversed, the globe of fire may disappear without report. If a portion of the storm cloud approaches the earth or another conductor, the lightning may strike at a distance at the same moment that the globe disappears. If the layer of air is pierced, there is a flash of lightning accompanied by thunder, which is not due to the small quantity of electricity enclosed in the globe, but to the sudden discharge of a large portion of the electricity of the cloud.—*Comptes Rendus*, Aug. 11, 1884. C.

ANNUAL SUMMARY OF ENGINEERING AND INDUSTRIAL PROGRESS—1884.*

THE SECRETARY:—In accordance with my custom at the first meeting of the new year, I beg to ask your attention to the following brief summary of the most noteworthy facts in the fields of engineering, mechanics and technology associated with the year 1884.

The statements given to the public during the past year of the condition of the work on the Panama Interoceanic Canal, and the prospects of its completion, were, as usual, of the most conflicting character. For reasons which it will be unnecessary to repeat, this project has never commanded the sympathy of Americans, on which account probably, unfavorable impressions and reports respecting it have found freer circulation in the newspapers than those of an opposite character. An impartial analysis of the facts at my command, justifies the statement that, in respect to the financial support of the enterprise, and the perfection of its engineering organization, and in the extent of the work actually accomplished, the Panama canal is in a fair way to be successfully completed within a reasonable period. The facts brought out in the last published annual report of the Count de Lesseps, and in the excellent *resumé* of Mr. Charles Colné, Secretary of the American company, presented in a paper read before this Institute, bringing down the statistics of the enterprise to September 1, 1884, leave no room for doubt on these points. From these data, it appears that over $100,000,000 have already been subscribed for the shares of the company, of which $25,000,0000, have already been expended in a needful preliminary work and in excavations. The line has been divided into sections, each of which has been, or will be, given out on contract. The total of excavations reported to September 1, 1884, was 10,224,882 cubic yards. This bears a small ratio to the total amount necessary to complete the canal—namely, 156,000,000; but it must be remembered that in a work of such magnitude as this, the preliminary steps are invariably the most difficult, expensive and tedious of execution. The fallacy of estimating the time required to finish the work, on the basis of that already accomplished, will appear from an inspection of the following data of work done during successive periods:

* From the Report of the Secretary, Wednesday, January 21, 1885.

	Cubic yds.
Work done previous to January 1, 1884	3,610,778
Work done in the first four months of 1884	3,217,460
Work done in the first eight months of 1883	6,614,104

From these figures, it appears that the work of actual excavation accomplished during the first eight months of 1884 was nearly double in amount to that excavated during the previous four years of work on the Isthmus. The argument of the opponents of the Panama canal, that after all these years "only one-thirteenth of the excavation is done," is thus seen to have no bearing whatever as a guide in estimating the possible time and cost of completing the work.

The transmittal by the President of the United States, to the Senate, of the project of a treaty between this government and that of Nicaragua, by the terms of which the United States is given the right to open across Nicaraguan territory an inter-oceanic canal that shall be under the exclusive control of the United States, again directed attention to the Nicaraguan canal project ,which has always been a favorite one with our government engineers. Pending the consideration of the treaty, the government has sent an expedition, under the direction of Mr. A. G. Menocal, U. S. N., to make a re-survey of the location on which the estimates of former surveys of the route, may be revised and verified.

The Nicaraguan canal, as projected, will be 172 miles in length, of which 119 miles will be furnished by lakes and rivers in which there is already sufficient depth of water, or in which such depth can be easily obtained. The probable cost is estimated to be about $60,000,00 or about one-half the cost of the Panama canal, as estimated by Commander Gorringe. The cost of the improvement of the harbors at the termini, however, which will be necessary, is probably not included in this estimate. The Nicaragua route has the advantage, it will be observed, of permitting the utilization of a natural water-way for about two-thirds of its length, It has the additional advantage of being about 800 miles further north than the Panama route. It has the disadvantage of being over four times as long as the Panama route and of requiring a complicated system of locks, of which about fifteen will be needed, and the failure or injury of any one of which would obstruct the entire line. The time required for the passage of vessels will be three days, as compared with as many hours by the Panama sea-level canal. In view of these unfavorable circumstances, and notwithstand-

ing the incontestible advantages of location, it has been, and is yet, a mooted question if such a canal could compete successfully for the world's traffic with a sea-level canal at some other point on the Isthmus.

The ship railway which Captain Eads has proposed to build across the Isthmus of Tehuantepec, about 800 miles further north than Nicaragua, has continued to attract attention, both at home and abroad. The project is unquestionably more favorably estimated, now that its features are better understood, than when it was first proposed. So far from being visionary or chimerical, the plans of Captain Eads are now generally admitted to be entirely practicable, and it is quite within the range of possibility that they may be realized.

The facilities of the Suez canal have of late been taxed to their utmost to accommodate the constantly increasing traffic passing through it, and in consequence of the frequent and expensive delays often experienced by vessels, it was found necessary last year to appoint a technical commission to determine upon the expediency of one or the other of the two measures of relief that are proposed—namely, to build a second canal, or to widen the existing one. This commission has just reported in favor of the last named proposition.

The cutting of a canal across the Isthmus of Corinth, which was begun in the year 1882 by a French company under contract with the Government of Greece, has been steadily progressing. The total length of the canal will be 6,933 yards (about four miles). At the present rate of progress the work will be completed in 1886. This work has some historical interest attached to it, inasmuch as the remains of ancient excavations pointing to early attempts to cut through this barrier between the Black and Adriatic Seas, are still plainly discernible. The canal will have the same width as that at Suez (75 feet) and will shorten the voyage from the Adriatic Sea to Turkey and Asia Minor by 185 miles.

From time to time reports have appeared of substantial progress of the work of draining the Florida everglades, which has been carried on for some years by a company of Philadelphia capitalists, though at this time no statistics of the work accomplished are at hand.

Of considerable engineering and commercial importance is the final completion and opening to traffic of the Arlburg railway. This enterprise was undertaken by the Austrian government, for the purpose of providing a more direct line of communication with Switzerland, and incidentally with France and Western Europe, independent of Ger-

many. The route of the railway is from Innsbruck, through the Tyrolean Alps to the Lake of Constance; and, in connection with the Swiss railways, it forms the most direct route between Austria (and Southeastern Europe generally) and Southern France. The line presented some exceedingly difficult engineering problems, of which the most notable was the great tunnel of the Arlberg, the third in point of length in the world. Work on this tunnel was commenced in June, 1880, and it was pierced in November, 1883. The rapidity with which the work was completed affords a notable example of the advances that have been made in the art of tunneling. Of other important works under construction, may be mentioned the Railway Tunnel, under the Severn river. This tunnel, which was begun in 1873 under the sanction of the British Parliament by the Great Western Railway Company, will, when finished provide uninterrupted railway communication between England and South Wales. The tunnel will be 7,664 yards (about 4⅓ miles) long. The works were flooded by an accident in 1879, but since that time considerable progress has been made, and at present the tunnel is rapidly approaching completion.

Since January, 1883, work has been in progress upon the great steel cantilever bridge across the Firth of Forth in Scotland, to take the place of that blown down by a storm some years before. This structure, when completed, will be one of the most notable of its kind in the world. It will have a total length of one and a half miles, and of its 22 spans there will be two of 1,700 feet each. There will be in the piers about 120,000 cubic yards of masonry, and in the superstructure 45,000 tons of steel. This great structure is being built under contract for £1,600,000.

The railway interests of the United States were among the principal sufferers by the industrial depression which existed throughout the past year, a fact which is abundantly proved by the great falling off in earnings, the enormous depreciation in values which railway securities of all kinds have suffered, and by the financial disaster that has overtaken so many railway companies during the year. The severe economy which the railway companies were forced to practice, is perhaps made most apparent by the large decrease in the mileage of new railway completed during the past year. On the authority of the *Railroad Gazette*, the miles of railway completed during the last seven years were:

1878.	1879.	1880.	1881.	1882.	1883.	1884.
2,916	4,570	7,174	9,789	11,506	6,753	4,350

The total mileage completed at the close of each of the last seven years, was, on the same authority:

1878.	1879.	1880.	1881.	1882.	1883.	1884.
81,774	86,497	93,454	103,242	114,838	121,592	125,942

The construction of 1884 is estimated, but will approximate closely to the true figures. Discounting the probable small error, my informant is sure that the new mileage of 1884 was much less than that of any year since 1879, when railway construction had but begun to feel the effects of the industrial revival. "Since 1879," remarks the *Gazette*, "the increase has been 39,445 miles, or 45½ per cent.; and here we have a sufficient explanation of anything that may be unsatisfactory in the present condition of railroad business."

The cable system of street car propulsion has received a noteworthy extension during the past year, by the construction of about ten miles of such railway for several of the leading street railway companies in Philadelphia, and which was about ready to be put in operation at the close of 1884. It is in contemplation to considerably extend these lines, and if the plans at present decided on are carried out, there will shortly be no less than twenty miles of cable railway in operation in this city. The system in question is in successful operation in San Francisco, Chicago, Detroit and Kansas City.

In the fields of electrics, several subjects of interest may be noticed. The persistent agitation of the question of underground wires has caused the enactment of mandatory ordinances in a number of the principal cities of the country, requiring the wires to be placed under ground after a certain date. Thus far, however, no solution of the question seems to have been proposed which would meet the requirements of the situation in a simple and satisfactory manner to all concerned. With the constant multiplication of the overhead wires in the cities, a period must soon be reached—if, indeed, it has not already been reached in some localities—where the nuisance of maintaining such lines must become intolerable. The present situation seems to be this: While the necessity of placing the wires in the cities, underground, is generally acknowledged to be growing more and more imperative, the problem of introducing the desired reform without imposing serious inconvenience and heavy pecuniary penalties upon the electrical interests, is likewise becoming more difficult to solve. Although some progress in the right direction seems to have been made in

New York, Philadelphia, Chicago, Boston and other cities, in every instance, I believe, it has been found necessary to extend the limit of time in the ordinances above referred to.

Arc lighting seems to be steadily growing in popularity for the illumination of streets, and other large areas. During the past year a careful series of experiments has been made under government direction to determine its practical value for lighthouse purposes; the results, however, do not appear to have been satisfactory in respect of economy. The incandescent lamp, also, has fully demonstrated its value as a means of interior lighting, and its use is steadily extending.

I regret that I am unable to record any substantial advance in the construction or efficiency of the storage battery, through which alone, as many believe, the general introduction of electric lighting, as a practical competitor with gas, will be made possible.

Substantial advance appears to have been made in perfecting the working details of the multiplex-synchronous system of telegraphy (referred to in my last year's summary), a line of which has been in operation the greater portion of the past year between Boston and Providence.

The final settlement, in favor of the Bell Company, of the long pending litigation involving the ownership of the telephone, was one of the notable events of the year. The hope is very generally expressed that the removal of this distracting element will have as one of its immediate results the increase and improvement of telephonic facilities. The promise is held out that long-distance telephoning will receive the immediate attention of the Bell Company, and the present year may witness the establishment of telephonic intercourse on a practical basis between a number of the seaboard cities.

In the direction of the electric transmission of power, it does not appear that any notable advance was made during the past year.

Of special interest in this connection was the International Electrical Exhibition, held in Philadelphia in the autumn of 1884, under the auspices of this Institute, and which afforded an excellent opportunity for the illustration of the most recent advances in the applications of electricity.

From the estimates of Mr. Swank, Secretary of the American Iron and Steel Association, I learn that during the past year the domestic demand for all the leading iron and steel masters was less than in 1883. We made less pig iron and bar iron, fewer steel rails, less steel

for miscellaneous purposes, and fewer kegs of nails. From the sources of information at his command, the Secretary estimates the production of pig iron in 1884 to have been at least equal to the production in 1880, which was the year of the "boom." The production in that year was 4,295,414 net tons of 2,000 pounds, or 3,835,191 gross tons of 2,240 pounds. This calculation, he thinks, will be found, upon the reception of the full returns, to be substantially accurate. Our imports of pig iron in 1884 declined to 225,000 tons, of which a large percentage was spiegeleisen for the use of our Bessemer works. It is yet too early to draw any reliable conclusions as to the production of Bessemer metal.

The trials of the basic process in this country do not appear to have given the favorable results that were anticipated of its use. For the present, at least, we are advised that the process has been abandoned.

In his summary of the events of the year, Mr. Swank concludes that the year 1884 was a bad year for the American iron trade, rendering necessary a general reduction of wages, the closing of many manufacturing establishments, and a progressive tendency to lower prices. During the year, for the first time, the influence of a new disturbing element began to make itself felt, namely, the competition of Southern pig iron, an influence which undoubtedly assisted in bringing about a reduction in the price of all pig iron; but the most potent causes of this decline were undoubtedly the competition among Northern producers and the general depression in trade.

The fact, however, that the stocks of iron in manufacturers' hands at the close of the year were no greater, if, indeed, they do not fall slightly below the figures of 1883, is a sign of encouragement, in that it shows that the restriction of production has reached its limit, and that the present production is not in excess of the demand. It is worthy of comment, likewise, that notwithstanding the widespread industrial depression for which the past year will be principally remembered, and the stringent economy which the railway companies, the principal consumers of iron and steel products, were forced to practice, the domestic consumption of iron was almost equal to the consumption of both domestic and foreign pig iron in the year 1880, the most remarkable, in the industrial annals of our country, for its productiveness and activity. This fact exhibits most strikingly the rapidity with which the industrial elements of the country are being developed.

The coal production of 1884 probably exceeded 60,000,000 tons, nearly equally divided between anthracite and bituminous.

The utilization upon a large scale of natural gas as fuel for manufacturing and domestic uses, as a substitute for coal, in and about Pittsburgh, is one of the most interesting, and, in respect to its bearing upon the industries, unquestionably the most important event of the past year. Beginning with the successful striking of a powerful vein of natural gas within the limits of the city by Mr. Westinghouse, a large number of wells have been sunk, and in nearly every case with good results. The developments already made render it quite probable that the whole city is underlaid by great gas reservoirs, which require only to be tapped in order to yield gaseous fuel in sufficient quantity to meet all the requirements of that city and vicinity for manufacturing and domestic uses. Already the new fuel has taken the place of coal in many of the leading manufacturing establishments in and near Pittsburg, and it is being rapidly introduced for the heating of buildings. The discovery of these abundant sources of cheap fuel in the city itself has opened a new industrial era in Pittsburgh. Those who know how large an item in the expense account of a manufactory is charged to its coal consumption, will realize the great advantages which the Pittsburgh manufacturers must derive from the possession of unlimited supplies of a fuel, in every respect superior to coal, and at greatly diminished cost.

The subject is exciting the most profound interest in Pittsburgh. A number of companies are engaged in the piping of natural gas from wells to manufacturing establishments and private dwellings. The daily supply at the close of the last year was estimated at 25,000,000 cubic feet. The formation of new companies and the sinking of new wells is going on so industriously that the supply must in a very short time very greatly exceed that quantity.

The cost of the gas at present is said to be 15 cents per 1,000 cubic feet; but it is anticipated that the inevitable competition which must arise, will bring the price down to 5 cents per 1,000 cubic feet. As is the case with all such new developments, the innovation must pass through its speculative period, and there appear to be serious difficulties to overcome in order to safely regulate the supply of a material under the enormous pressure (often 150 to 200 pounds to the square inch) at which the natural gas issues from the wells. But when the speculative craze shall have subsided, and engineering skill shall have pro-

vided the necessary mechanical artifices to safely regulate its distribution, the possession of these vast supplies of gaseous fuel must give to Pittsburgh decided advantages in the development of the industries which have already made her famous.

The discovery during the past year of an agent which possesses the remarkable property of producing local insensibility, has placed in the hands of the surgeon another invaluable agent for the alleviation of pain in some of the most severe surgical operations. The agent in question is the active principle of coca (cocaine); and, in the form of the hydrochlorate, an aqueous solution of from 2 to 4 per cent. strength has been found to produce complete insensibility in the delicate membranes of the eye, so that the operations for cataract and other surgical operations upon this sensitive organ, which were formerly attended with exquisite suffering, are now performed without pain. The agent appears to act, though not with the same promptness and certainty as upon the eye, as a local anæsthetic of general applicability.

Referring to my allusion last year to the important bearing of Parteur's experiments in rendering harmless the virus of hydrophobia, it is of interest to note that a commission of savants appointed by the French Academy, has after a careful repetition of Parteur's experiments and study of his methods, fully confirmed his announcement that he had succeeded in rendering dogs proof against the disease. Important results are affirmed to have been obtained in the direction of rendering harmless the contagion of yellow fever, the scourge of tropical and semi-tropical America, by a system of inoculation with a modified virus, which renders the patient safe from the virulent form of the fever. The inoculation is said to be systematically carried on in Rio Janeiro, and with the best results.

In the field of aerial navigation, the past year witnessed some interesting experiments which appear to show that under favorable circumstances, considerable success may be had in directing the course of a balloon provided with suitable steering apparatus. The experiments here referred to were made in France by Captains Renard and Krebs.

It may be important to note that the manufacture of soda, by the ammonia process, is now to all appearances firmly established as a home industry. From information received, I am able to state that the Solvay Process Co., located at Geddes (near Syracuse) N. Y. (the pioneer, let us hope, of many to follow), have met with entire success

in their enterprise. The present producing capacity of the works is 15,000 tons per annum, and the plant is about being doubled.

The continued successful operation of the Alverado Beet Sugar Company, at Alverado in California, is likewise a noteworthy circumstance. Over one million pounds of beet sugar were made at this establishment during the last season's campaign, and this in the face of direct competition with the Sandwich Island sugar imported into this country, duty free, under the Hawaiian Islands reciprocity treaty. The continued financial success of this company, convincingly demonstrates that the only questions involved in the successful domestication of this important industry, are that of proper methods and proper management.

An international conference was held at Washington during the last year, at which, the representatives of 24 nations were present to determine upon the selection of a prime meridian to be recommended for adoption by all the nations interested therein. This conference decided by an almost unanimous vote to recommend the selection of Greenwich as the universal prime meridian. It will doubtless be adopted in all the future official publications of the United States Government.

The importance attaching itself to the production of tin in the United States renders highly interesting the announcement made early in the past year, by Prof. Wm. P. Blake, that tin ore in large quantity existed in the Black Hills in Dakota. Subsequent more thorough examination has fully confirmed the fact that these deposits are both extensive and valuable. Discoveries of ores of tin have also been announced on credible authority in Rockbridge co., Va. It is probable, therefore, that this country will soon become a producer of this important metal.

SOLAR PHENOMENA IN SWITZERLAND.—In his descriptions of the colored rings by which the sun has been so often surrounded of late, Forel says that there is nothing which resembles a halo. It is a corona, which is not dependent upon the meteorological condition of the air in its lower regions. We are therefore driven to the conclusion that there is a cloud of dust suspended in the upper layers of the atmosphere. He invites the especial attention of naturalists, physicists and travelers who penetrate the upper strata of the atmosphere, whether on mountains or in balloons, to the phenomenon, and to a careful study of all the facts which they may observe.—*Comptes Rendus*, Sept. 1, 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, January* 21, 1885.]

HALL OF THE INSTITUTE, January 21, 1885.

MR. WILLIAM P. TATHAM, President, in the Chair.

Present, 164 members, and 8 visitors.

Eight persons were reported as having been elected members since the last meeting.

Ths Actuary reported the following resolutions adopted by the Board of Managers at their stated meeting of January 14, viz.:

Resolved, That the Standing Committee on Exhibitions, recommend to the Board the holding of an Exhibition in the fall of 1885, provided the lot of ground occupied by the Exhibition building at Thirty-second street and Lancaster avenue can be leased of the Pennsylvania Railroad Company for the purpose.

Resolved, That the Exhibition to be held shall be called the "Novelties" Exhibition.

Resolved, That the Secretary have blank forms printed for a Guarantee Fund of not less than $20,000, and that a copy of the same be sent to each member of the Institute.

Annual Report of the Board of Managers for the year 1884.

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1884:

MEMBERSHIP.

Number of new members elected		510
Lost by death or resignation	16	
Dropped for non-payment of dues	33	49
Net accessions to membership		461
The total membership at the close of the year 1884 was (approximately)		2,050

FINANCIAL STATEMENT.

Receipts.

Balance on hand, January 1, 1884	$657 57	
Cash received from exhibition	6,909 58	
Cash received from other sources	17,941 97	
		$25,509 12

Payments.

Cash paid interest on exhibition loans	$577 02	
Cash, all other current payments	18,002 30	
		$18,579 32
Balance on hand, December 31, 1884		$6,929 80

THE LIBRARY.

The growth of this branch of the Institute during the year 1884 has been fully maintained. Through the regular channels, the additions have been 2,547 volumes and pamphlets, to which should be added the valuable collection of special works on electricity and magnetism made for the exhibition, and which comprises 2,976 volumes and pamphlets. The total additions to the Library during the year are thus swelled to 5,547. The details will be found in the report of the Library Committee.

The old grievance of the insufficiency of room for the accommodation of the Library still exists and increases. The Board can only refer to what has been said on the subject in previous reports.

THE JOURNAL.

The business of the JOURNAL during the year 1884, though showing a slight decrease as compared with the figures of the previous year, has on the whole been satisfactorily maintained.

LECTURES.

The following lectures were, with the approval of the Board, arranged for, and delivered during the year 1884:

By Dr. Constantine Fahlberg, *three* illustrated lectures on Chemical Technology; Prof. Geo. A. Koenig, *two* (illustrated) on the Metallurgy of Silver; Prof. M. B. Snyder, *five* (illustrated) on Electricity; Mr. Theo. D. Rand, *four* (illustrated) on Mineralogy; Prof. A. J. Parker, *ten* on Animal Physics and Mechanics; Mr. Coleman Sellers, Jr., *one* on Drawing; Mr. Henry R. Towne, of Stamford, Conn., *one* on Cranes; Mr. George M. Bond, *two* on Standards of Length; Prof. Persifor Frazer, *one*, Introductory to the Chemical Course (illustrated); Mr. Richard D. Baker, *two* on Elementary Chemistry (illustrated); Wm. H. Greene, *two* on Applied Chemistry (illustrated); Dr. Bruno Terne, *two* on Agricultural Chemistry; Mr. C. John Hexamer, *two* on Fire Hazards in Textile Mills; and Prof. Persifor Frazer, *one*, Christmas Lecture to Young People (illustrated).

The above comprises thirty-eight lectures during the year. The attendance thereon was about up to the usual average of former years. The plan of issuing free tickets, admitting five minutes before the commencement of the lecture, has been continued, and appears to give general satisfaction.

DRAWING SCHOOL.

The number of pupils attending the Drawing School during the year 1884 shows a slight falling off when compared with the year

1883, which may probably be ascribed to the prevailing industrial depression. The high efficiency of the school, however, has been maintained, and improved methods of instruction and increased facilities for illustration have been introduced.

The total number of pupils in attendance during the spring term was 166, and of those at the winter term 178, making a total of 344. Some additional room has been gained for the school in the third story, by the removal of two large cases formerly devoted to the models. The Director reports that the Architectural Class is the largest we have ever had. Considering the general stagnation of all the industries, and the competition of other similar schools, which solicit and receive aid from the public, the Board feels much gratified to report that the condition of the Drawing School of the Institute is entirely satisfactory.

EXHIBITION.

During the month of September and part of October last a special exhibition of electricity, and of the means for its generation and application was held by the FRANKLIN INSTITUTE.

Notwithstanding the great expense attending the erection of buildings and machinery, the exhibition was signally successful, and it is hoped that the reports to be expected from the Examining Committees chiefly composed of gentlemen of the highest scientific reputation may be of great interest, and of value to science.

Too much praise cannot be given to the Joint Committee of the Board and Institute which managed the enterprise and brought it to a successful completion. To this and the generous liberality of the Pennsylvania Railroad Company we are indebted for the result.

The Board has had under consideration the subject of another exhibition next fall, and application to the Pennsylvania Railroad has been made for a positive lease of the ground for this year, but at this date no answer has been received.

In anticipation of a favorable answer, the Board, after mature consideration, at the meeting held on January 14, 1885, resolved to hold an exhibition to be known as a "Novelties Exhibition," and to be devoted to such recent inventions and improvements in the arts, manufactures and sciences as may be deemed worthy the name. As a preliminary step arrangements were ordered to procure a suitable guarantee fund.

SECTIONS.

The Chemical, Electrical and Phonetic Short-Hand Sections have held regular monthly meetings during the year, and the Board refers to their annual reports with pleasure, as showing a gratifying growth of their usefulness.

THE COMMITTEE ON SCIENCE AND THE ARTS.

This Committee passed upon sixteen applications during the year, in four of which they recommended the award of the John Scott legacy premium and medal. Of these recommendations two were confirmed by the Institute and approved by the Board of City Trusts, and two are still pending.

By order of the Board,

WILLIAM P. TATHAM, *President.*

PHILADELPHIA, January 14, 1885.

Report of the Committee on the Library for the year 1884.

The Committee on the Library presented the following report:

The Committee on the Library respectfully report that, during the year 1884, there has been added to the Library, on general account—

Bound volumes	1,039
Unbound volumes	480
Maps and charts	24
Pamphlets	1,028
Total	2,571

To this is to be added the "Memorial Library," which now forms part of the General Library—

Bound volumes	660	
Unbound volumes	269	
Pamphlets	1,948	
Serials	82	
Manuscripts	13	
Excerpta	4	
Total		2,976
Total addition during the year		5,547

Total number of volumes in the Library, exclusive of pamphlets, December 31, 1884, was 20,792.

A large number of valuable serial publications have been bound during the year, and a number of volumes have been rebound.

EXCHANGES.

Two hundred and sixty-seven publications, in the Library, were received in exchange for the JOURNAL during the year. Of these 136 were foreign and 140 domestic.

DUPLICATES.

The Librarian has prepared a catalogue of duplicates, which will be printed and distributed among public institutions, for the purpose of effecting exchanges.

SERIAL PUBLICATIONS.

Thirty-three serial publications have been completed during the year. Some of them, of great importance, were completed with difficulty, on account of the large gaps which were found to exist in the series.

The Committee are much indebted to one of their members—Mr. Lewis S. Ware—who, while in Europe during the past year, materially aided them in this work, as also in the advantageous purchase of many new works.

CASE ROOM.

Although new cases, of the capacity for 3,000 volumes, have been erected during the year, room is still required for about 2,000 additional volumes. The library room is now so full that but little additional space is available for the farther accommodation of book-cases.

A revised edition of the catalogue of the Memorial Library, revised and enlarged, has been prepared by the Librarian, and the revised proofs are now in the printer's hands.

Respectfully submitted,

CHAS. BULLOCK,

December 31, 1884. *Chairman of Committee on Library.*

The following report was presented by the Representative in the Pennsylvania Museum and School of Industrial Art, upon the operations of the Institution for the year 1884:

To the President and Members of the Franklin Institute:

Your Representative in the Pennsylvania Museum and School of Industrial Art offers the following report of the operations of the Museum and School for the past year:

The history of the Institution for the year is marked by only two events of interest.

First. The gift of fifty thousand dollars by Mr. J. E. Temple, in trust, the interest to be paid to him during his life, and to be used after his death for the purchase of objects for the collection and for prizes in the schools.

Second. The purchase of premises No. 1336 Spring Garden street, the removal of the School to these premises, and the extension of its departments into instruction in wood-carving, weaving, and allied branches. Beyond this, the history of the Institution has been uneventful.

Very respectfully,

WILLIAM H. WAHL, *Representative, etc.*

The Chemical and Electrical Sections also presented reports of their operations during the year.

The above reports were severally read and accepted.

Following, is a list of officers chosen at the annual election held this day:

For *President* (to serve 1 year), William P. Tatham.

For *Vice-President* (to serve 3 years), Joseph E. Mitchell.

For *Secretary* (to serve 1 year), William H. Wahl.

For *Treasurer* (to serve 1 year), Samuel Sartain.

For *Managers* (to serve 3 years), William Sellers, Hector Orr, Cyrus Chambers, Jr., Henry R. Heyl, Charles J. Shain, Charles E. Ronaldson, G. Morgan Eldridge, Hugo Bilgram.

For *Auditor* (to serve 3 years), William B. Cooper.

For *Representative in the Pennsylvania Museum and School of Industrial Art* (to serve 1 year), William H. Wahl.

COL. CHAS. H. BANES spoke as follows. "Mr. President:—I beg the indulgence of the Institute for a few moments to discharge a very pleasing duty. It is a pleasing duty, and yet brings with it some degree of onerous cares. At the early part of the preparations for the late Electrical Exhibition, it was deemed advisable to form a collection representing the literature of electricity. It was determined that proper efforts should be put forth, and proper documents sent, to authors, publishers and governments that would induce contributions to this library, which should not only be a memorial of the exhibition we have held during the last year, but should also be a valuable library for research and reference. The sub-committee to which the work was entrusted has discharged its duties very well, as you have heard from the report of the Library Committee just read by the Secretary, giving information as to the extent of its work. In extending an invitation for contributions, this sub-committee had published a document in which it agreed to do certain things. I have been requested by the sub-committee, through you, Mr. President, to make over this very valuable "Memorial Library" to the care of the Institute. I desire to ask your attention for a moment to the letter put forth by the committee, so that you may see what trust we have undertaken (reading the letter). I would say, sir, that in reply to this communication addressed to publishing houses, authors, editors, electricians and governments, there have been received thus far 3,432 volumes, bound, unbound and pamphlets. I wish to say just here, that this word "pamphlets" does not describe the full value of the communications or printed papers usually classified as pamphlets. You will find that they contain in many cases the record and evidence of original research that does not exist except in a very limited number of publications privately distributed by the inventor or discoverer among his friends and colleagues. Some of these are exceedingly interesting. One, I remember, where an investigator sent not only his papers bound, but gave the illustration of processes by which he arrived at certain results of experiments. In this collection are many volumes received from the Belgian Government; and only to-day there were received from the Italian Government over 50 volumes not included in the committee's report. Thus, you see, we may hope to receive accessions from time to time. I deliver to you, as President of the Institute, this very valuable library to be held in trust as indicated in the appeal made by the committee."

THE PRESIDENT:—"The Franklin Institute receives, with the greatest pleasure, this gift, which is the result of the enterprise and assiduous labors of the Committee on Bibliography. During the past six months I have been filled with admiration when I saw its methods of procedure, its well-